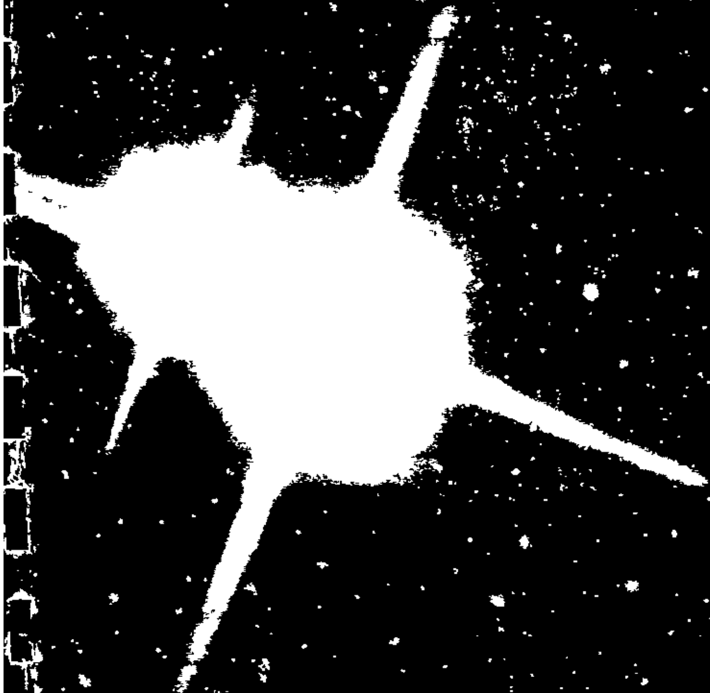
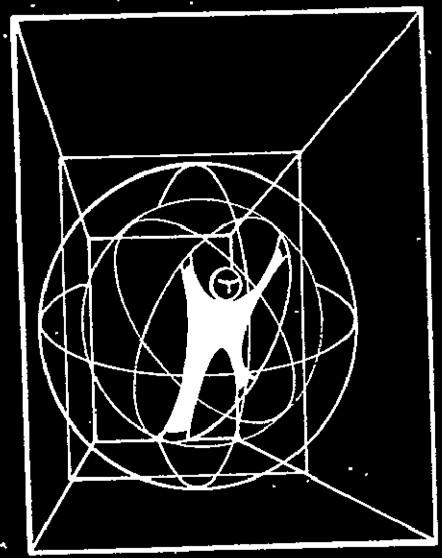
Report No. 70-6651





HABITABILITY

GUIDELINES AND CRITERIA

2-P (MIX)

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HABITABILITY GUIDELINES AND CRITERIA

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NASA Contract Monitor: H. Watters

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FOREWORD

The study described herein, which was performed by the Life Sciences Department of the AiResearch Manufacturing Company, a division of The Garrett Corporation, was performed under NASA Contract NAS8-25100. The contributions of Robert Irwin, which include consultation in aesthetics and the infrared oven mockup shown in figs. 5-1 and 5-2, are gratefully acknowledged. The mockup of the audiovisual viewer (fig. 5-3) was contributed by Billy Al Bengston.

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SECTION 1

INTRODUCTION

1
INTRODUCTION

This document represents a portion of a design study performed by Garrett/AiResearch for the Marshall Space Flight Center, National Aeronautics and Space Administration, under Contract NAS 8-25100. Other products of the design study exist in various mockups and models located at either the Douglas Street facility of Garrett/AiResearch in El Segundo, California, or at Marshall Space Flight Center, Huntsville, Alabama.

The contract monitor for this program was Mr. Harry Watters, Chief of Manned/System Habitability and Technology Section, NASA MSFC.

Designs and criteria for the habitability of a long-duration multiman space station were produced by a comprehensive study beginning with a literature search of applicable multicrew long-term missions; progressing to development of habitability evaluation parameters; and concluding with analytical and design studies of three major types of spacecraft compartments--the sleeping, wardroom, and hygiene compartments. The study was directed toward zero-g conditions for a 12-member crew. Since future long-duration missions probably will be conducted with crews of both sexes, the differing requirements for female crew members in some areas were considered. However, cultural differences were not considered in the study of habitability and the resulting definitions of space modulators.

Valuable sources of information for the study were (1) existing human factors data, (2) architectural standards, (3) the Tektite II undersea program, and (4) a Habitability Symposium.

The Tektite II program provided a unique opportunity to measure and observe human reactions to an isolated habitat during actual missions. Consequently, a research program directed at the problems of measurement of habitability also was performed under this contract. Although the duration of these undersea missions was only two to three weeks, sufficient data were collected to provide insights about many factors and definite conclusions and recommendations about others. The results of the habitability research on Tektite II will be published seperately.

A symposium on habitability was conducted in Los Angeles on May 11 through 14, 1970. This symposium, funded jointly by NASA and Garrett/AiResearch, represented the first assembly of relevant specialists for the purpose of defining habitability and exploring the problems of providing for habitability. Dr. Stanley Deutsch, Chief, Man Systems Integration Branch, Biotechnology and Human Research Division, Office of Advanced Research and Technology, directed and coordinated the NASA participation in this symposium. The symposium provided a sounding board for the exchange of ideas and the discussion of views on particular problems by specialists in the numerous diverse disciplines. This amalgamation of science, arts, and humanities tended to focus on the

philosophical aspects of the habitability problem. However, the importance of various design factors that affect such things as personal space and personal territory also were considered. A report on this symposium has been published in four volumes by Garrett/AiResearch.

Information from the sources described above provided the basis for the conceptual designs and analytical design studies performed in this program. The approach taken for the study was to define those aspects of the compartment interiors having a direct bearing on crew efficiency and feeling of well being during long-term confinement.

Human engineering data on man/machine relationships are easily obtained from many sources. Because these data are available, only those areas not previously covered were considered for this study. Items such as personal space, personal territory, zero-g maneuverability, and interior volumes are among those parameters not previously dealt with in spacecraft design that were investigated in this study. Factors such as the aesthetics involved in creating tension between positive forms in negative space are highly complex. The interrelationship of culture, individual preference, and experiences result in highly personal solutions. The wide range of tastes and the effects of habituation over time combine to suggest multiple or varied interior arrangements instead of one initial design solution that is built into the craft as in current vehicles. It is recognized that tastes vary widely and that some crew members will not be able to arrange an interior to their satisfaction without help from others. Helping each other in an area as personal as aesthetics is an excellent method of promoting group cohesion. Privacy and perceptual richness of the interior are both important factors that must be properly controlled for efficiency during long-term confinement.

In addition to the analytical work performed, a mockup was constructed to provide a space frame for the observation of volumes selected for the various activities. Typical spacecraft activities were defined as a result of the functions analysis and used as design inputs. Typical furnishings and spaces were designed and mocked up for evaluation. No attempt was made to design a specific craft interior because of the numerous variables associated with the final selection of hardware. Various alternate solutions to the design of sleep, hygiene, and wardroom situations were examined along with a methodology for designing to satisfy specific functions. When the form is given or defined, as in spacecraft, functions to be performed must be investigated to determine whether they can in fact be performed within the given volume. This partially reverses the approach of the design axiom that "function" defines the form. Imposing these design constraints creates a design challenge of balancing human performance against minimum standards; minimum standards for an 8-hour day, 5-day week are not the same as those required for a long-duration isolated habitat.

The point of departure for this analytical study was the current body of information and understanding with respect to habitability. The authors believe that this vantage point is wholly inadequate for the objectives of ensuring the well being of humans in long-duration spacecraft missions. Sequential programs

involving the development and test of appropriate concepts, theoretical structures, and applied techniques of providing for habitability are required to ensure the ability to provide adequate spacecraft designs for long-duration missions.

This design study, however, together with the habitability research on Tektite II and the Habitability Symposium, have provided an excellent point of departure for the effort necessary for a true understanding of how to provide for man's well being in confined and isolated environments.

SECTION 2

MEASUREMENT OF HABITABILITY

2

MEASUREMENT OF HABITABILITY

The concept of habitability is a vague one. The dictionary states that the word pertains to how fit an environment is to live in. Another working definition that has been found useful indicates that habitability is the perception of the quality of life in an environment. The Larson model of habitability (ref. 1) is compatible with these definitions, but has attempted to delineate the concept more fully. The Larson habitability model is described in Appendix A. In this section, methods designed to measure some social, psychological, and physiological aspects of the habitability concept are discussed.

Three main approaches for obtaining measures of habitability are: (1) reports from individuals living in the habitat on relevant observations and reactions, (2) ratings kept by impartial observers recording behavior observed in the environment under study, and (3) ratings based on examination of various features of the environment when studied separately. Measurements of aspects of habitability allow:

(1) Prediction of likely human responses to prolonged exposure to a particular habitat under study

(2) Identification of specific problem areas causing less than optimum habitability

(3) Better understanding of the psychological adjustment process to a habitat

(4) Better understanding of individual variations in adjustment to a habitat

(5) Provision of general evaluative data on the assessable habitability of particular environments

Such information could be used to improve planning and design for particular physical habitats, or improve personal adjustment to a habitat without modification of the habitat itself, or improve the selection process for choosing people to undergo prolonged stays in the habitat.

Development of general habitability scales may be premature because of the considerable complexity involved and the lack of available objective indexes. Currently, there is a need to specify as many of the factors involved as

possible, and a battery of assessment techniques that incorporated such factors may be a feasible approach. In this report, as many as possible of the most important of these factors are identified.

The types of assessment that could be used in studying factors that affect habitability are discussed in the following subsections. Also, the types of covariance that will be exhibited between these measures are predicted.

The field of habitability is somewhat like the field of meteorology because almost everyone is a lay expert. People frequently make decisions based on their amateur analysis of what the weather will do, and even more so, employers, hosts, owners of business establishments, husbands and wives, and others make guesses, some of them quite sophisticated, about what kinds of effects a particular environment is going to have on the people who come into it. Bearing the parallel between habitability and meteorology in mind, the following quote from a professional meteorologist in the introduction to his book on local weather is of interest:

> "The human race, by and large, is made up of amateur meteorologists. Most of your life you have been becoming one; so have all the other people who glance at the sky before going on a picnic or heading for a baseball game.....
>
> .....You are not, however, a meteorologist in the broad sense of the term. You are a specialist. The sweep of meteorology embraces everything atmospheric from the tiniest drop of dew on a blade of grass to the most terrible storm over the face of the earth. Your area of specialization encompasses only that part of the weather that you can see from the front porch, south forty, or picture window, depending upon your particular station in life. But within these relatively narrow confines, usually a few tens of miles or at most a hundred or so, there is much to behold that is within the province of the meteorologist. He calls it local weather. The chances are pretty good that you and your neighbors know more about your local weather than does anyone else in the world." (ref. 2)

As Edinger states, the key thing that distinguishes that amateur from the trained meteorologist is the latter's ability to bring a broader base of understanding to meteorological phenomena. The program delineated in this report is oriented toward further development of such broad base understanding of habitability. Scientists can also contribute to the understanding of habitability by making the problem more amenable to empirical analysis. This task of making the questions susceptible to scientific inquiry is emphasized in this report.

BACKGROUND

Surprisingly little research has been done in the field of habitability. What has been done gives considerable support to the theory that one's surroundings exert a strong influence over one's behavior.

Maslow and Mintz (ref. 3), for example, showed that the aesthetic quality of a room has a strong effect on subjects' tendencies to perceive "well-being" and "energy" in a standard series of photographs of people's faces. Compared to perceptions done in an average room, an aesthetically beautiful room led to increased perception of well-being and energy, and an ugly room led to decreased perception of these same qualities.

Zinner (ref. 4) studied the probabilities of various observable behaviors in various environmental situations. He found that situations he studied exerted a powerful force on observable behavior. He then concluded: "These results imply that once one has ascertained the probability that various situations will evoke or suppress behaviors considered desirable or undesirable, one may increase probable occurrence of desirable behaviors by modifying the environment." This statement is based meaningfully on empirical data and does provide justification for the importance of habitability research on man-made environments.

Similarly, Moos (ref. 5), Moos and Houts (ref. 6), and Fairweather et al, (ref. 7) have gathered a considerable amount of evidence to indicate that the "atmosphere" (a concept closely related to habitability) of mental hospitals has considerable effect on behavioral tendencies of residents, and furthermore, it is related to cure rate. Conversely, studies in psychiatric epidemiology such as those reviewed by Kramer (ref. 8) have helped to establish a link between habitat and mental illness. A particularly good example in this respect is that of Wilner, Walkely, Pinkerton, and Tayback (ref. 9), who studied two matched samples--one provided with good housing and the other with poor housing. Numerous indexes gave support to the hypothesis that better housing leads to lower morbidity rates and better mental health.

Calchoun (ref. 10) furthermore has shown that crowding in habitats can produce marked changes in animal behaviors. Rats in high population density areas show extremely high infant mortality rates and much higher rates of disturbed eating, sexual, and maternal activities than rats in normal population density habitats.

Thus, there is evidence that habitat can have a significant effect on behavioral tendencies. In fact, some researchers, such as Gump, Schoggen, and Redl (ref. 11), Rausch, Farbman, and Uewellyn (ref. 12), and Stern (ref. 13), find that surroundings exert at least as much influence on emitted human behavior as does personality.

Research on the prolonged habitation of extremely simple environments should be useful in increasing knowledge of the effect of habitat on behavior. Where there is simplicity of goals, leadership requirements, facilities, communications, and accompanying isolation from other factors that exert influence over the individual beyond that of habitat, empirical identification of the psychological effects of the habitat is particularly feasible.

ORIENTATION

Many measurement techniques should be and are currently being tried in the study of isolated environments (ref. 14). In this paper, a battery of assessment techniques has been formulated that is amenable to the general requirements for the selection of habitability measures listed below:

(1) Measures should be as simple as possible.

(2) Measures should have theoretical relevance to the construct habitability (Appendix A).

(3) A wide domain of habitability levels should be examined.

(4) Measures should be as nonintrusive and nondisruptive as possible.

(5) Hypotheses for each measure should concern (a) its temporal variation, (b) its overall covariation with other measures selected in the study, (c) its ability to predict changes in other variables measured in the study, (d) its responsiveness to recordable changes in the on-going situation, and (e) its variations in individuals in the situation.

(6) A plan for empiricizing and analyzing each measure should be made in advance.

(7) Wherever possible, temporal variations in variables should be studied.

(8) For any measure repeated 10 or more times, reliability estimates should be made by comparing odd days with even days and excluding in advance any days on which the environment was for some reason distinctly unusual.

(9) Where possible, heterogeneous methods of observation should be used in making measurements at any one particular level of habitability.

(10) When possible, measures chosen already should have demonstrated reliability, validity, and usefulness in earlier studies.

The reasons for most of the constraints should be easily inferrable; generally, in measuring aspects of habitability, experimental intrusion into the habitat should be minimized, and the relationship of the data to models of habitability and hypotheses generated from these models should be maximized. When possible,

it is recommended that extant tests be used in the battery because test construction and development is a particularly slow and expensive process.

Another constraint is change in measures over time. Temporal variations have not been the object of extensive study in habitability so far, but they should be a rich source of information as to the habitability adjustment process; also, they provide a way of maximizing the amount of habitability information that can be obtained from any one isolated environment study. Interest in temporal variation readily leads to the question of reliability of indexes. Flugel, one of the pioneers in studying variations in covert response to non-laboratory environments, was the first to use the method of odd versus even days for assessing reliability (ref. 15). If the effects of the habitat are persistent ones and the test is well built, these reliability scores should be high.

Various levels of the habitability concept are listed with recommended tests for assessment of each level in table 2-1. Three kinds of problems are involved: (1) measuring on-going responses (via self-report, observation, and physiological recording) during confinement in the habitat, (2) measuring habitability by evaluation of the properties of the habitat itself, and (3) gathering background data on each person undergoing confinement in the habitat.

MEASUREMENT OF ON-GOING RESPONSES DURING STAYS IN THE HABITAT

Of the three types of problems listed above, measurement of on-going responses during stays in the habitat requires the widest array of assessment procedures. Three primary measurement techniques involved in monitoring this on-going activity are (1) self-report, (2) observation of overt behavior, and (3) observation of physiological behavior. Whatever the measurement technique, many repetitions of the test must be made; all tests of this sort should be given at least once a day. In analyzing these data, temporal covariation of tests will be examined, and the means for each measure will be calculated for the duration of the test period; the temporal variations and means will then be related to other known features of the habitat and the personalities of the various subjects.

On-Going Self-Report Assessment Techniques

For habitability to be meaningfully studied, some estimate of on-going covert response to the environment under study must be made. This can be done through trained self-report, mood checklist sampling, attitude measurement, and content analysis of guided diaries.

The mood checklist sampling technique consists of having subjects fill out one-minute adjective checklists describing their immediate mood or internal state at specified intervals during the course of the actual period under study (ref. 19). This technique is advantageous because subjects can fill out the checklists with little disruption of normal routines. Also, measures are obtained with each administration of the checklist of each covert behavior

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TABLE 2-1

HABITABILITY ASSESSMENT TESTS

Test	Level of Habitability Hierarchy	Used Previously in or Adapted From	Type of Measure	Type of Analysis	Frequency of Administration	Length of Administration	Time Test Administered	Reliability Check	Validity Check	Number of Variables	Variables Derived	Predicted Covariation
Trained Subjective Report	Subjective-internal	Original	Trained self report	Mean for duration, temporal variations, correlations	3 times a day	5 min	During test	Odd against even days	Part of training done against polygraph	2	Relaxation and activation; Variables may be further mathematically defined through proximity analysis of training data	Activation and relaxation factors of mood scale
Semantic Differential	Subjective-attitudinal	Osgood, Suci, and Tannenbaum (ref. 16), Moos (ref. 5)	Self report	Mean for duration, daily variations, correlations	Once a day	20 min	During test	Odd against even days	Predicatable variations and correlations	3	Attitudes toward self, food, environment	Mood, habitability assessment rating scale, guided diary
Guided Diary	Subjective-evaluative and reporting	Should include: Performance Report (Radloff and Helmreich, ref. 14), Accident Report and General Assessment Report (Ben Franklin Mission ref. 17)	Self report	Reading for impressions	Once a day	30 min	During test	None, unless content analyzed	None, unless content analyzed	0	Personal assessment of habitat, and general information background	Could be used "blind" to predict variations in other measures
Mood Adjective Checklist	Subjective-mood	V. Nowlis (ref. 18), D. Nowlis and Cohen (ref. 19), Moos (ref. 5)	Self report	Mean for duration, daily variations, correlations	Every two waking hours	1 min	During test	Odd against even days	Predictable variations and correlations	10	Activation, deactivation, relaxation, pleasantness, depression, aggression, anxiety, social affection, egotism, concentration	Trained subjective report, attitudes
Location Record	Overt behavior	Radloff and Helmreich (ref. 14)	Electronic instruments	Means for selected time periods	Duration of test	Continuous	During test	Odd against even days	Test of instruments before and after tests	4	Food time, sack time, work time, gregariousness	Attitudes
Communication Topside and Home	Overt behavior	Radloff and Helmreich (ref. 14)	Communication log	Daily variations, correlations	As needed	Continuous	During test	None	None	1	Number of contacts outside group	Mood, attitude
Leisure Activity Record	Leisure time	Fraser (ref. 20)	Could be part of diary, or separate log	Daily variations	As needed	5 min	During test	None; unless content analyzed	None, unless content analyzed	0	Record of leisure activities	Will probably show change over time
Interpersonal Diagnostic Report	Social intercourse level	Leary (ref. 21)	Observers' rating	Mean for duration, daily variations, correlations	Once a day	1 hr	During test	Odd against even days	Predictable variations and correlations	7	Managing, being responsible, cooperating, being docile, rebelling, aggressing, competing	Attitudes
Percent time REM sleep	Physiological	Ben Franklin Gulf Stream Mission (ref. 17), Thayer (ref. 22 with Mood Check List)	EEG AND EMG (Polygraph)	Daily variations, correlations	Each extended sleep period	Length of sleep period	During test	Established	Established	1	Percent REM	Mood, level of stimulation, length of stay
Frontalis EMG Level	Physiological	Budzynski (ref. 23)	Polygraph	Daily variations, correlations	Once a day	20 min	During test	Odd against even days	Predictable variations and correlations	1	No. Microvolts EMG	Trained subjective report
Finger Volume or Temperature	Physiological	Lacey (ref. 24 and 25)	Polygraph	Daily variations, correlations	Once a day	During ancillary tests		Odd against even days	Predictable variations and correlations	1	Rate of habituation	Mood, level of stimulation, length of stay
Habitability Assessment Rating Scales	Evaluation of all physical features of habitat	Original	Pencil and paper	Item by item and overall means	Once	30 min	Posttest	Subject against subject	Informal comparison with diaries	1	Overall physical support of habitat	Background data

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TABLE 2-I (Continued)

Test	Level of Habitability Hierarchy	Used Previously in or Adapted From	Type of Measure	Type of Analysis	Frequency of Administration	Length of Administration	Time Test Administered	Reliability Check	Validity Check	Number of Variables	Variables Derived	Predicted Covariation
Sensible Variety in Habitat	Sensory	Berlyne, Ogilvie and Parham (ref. 26), Yoshida (ref. 27), Indow and Takagi (ref. 28)	Observers' rating	Sense by sense	Once	One day	Pretest or posttest	Observer against observer	None	3	Amount of visual, auditory, and tactile variation in habitat	Background data
Manifest Anxiety	Personality	Spence (ref. 29)	Questionnaire	Record of inhabitants involved	Twice	20 min	Pretest and Posttest	Established	Established	1	Anxiety	Background data
Hypnotic susceptibility	Personality	Hilgard (ref. 30)	Behavioral test	Record of inhabitants involved	Twice	1 hr	Pretest and Posttest	Established	Established	1	Susceptibility to hypnosis	Background data
Reaction to Monotony	Personality	Weybrew (ref. 31)	Behavioral test	Record of inhabitants involved	Twice	1 hr	Pretest and Posttest	Tentatively established	Tentatively established	1	Reaction to monotony	Background data
Sociometric Workup	Social	Radloff and Helmreich (ref. 14)	Questionnaire	Record of social patterns	Twice	20 min	Pretest and Posttest	Established	Established	0	General picture of social structure	Background data
MMPI	Personality	Welsh and Dahlstrom (ref. 32)	Questionnaire	Record of inhabitants involved	Twice	1 hr	Pretest and posttest	Established	Established	9	Personality traits	Background data
Millers Analogies	Intelligence	Miller (ref. 33)	Questionnaire	Record of inhabitants involved	Twice	1 hr	Pretest and posttest	Established	Established	1	Intelligence	Background data
Edwards Personal Performance	Values	Edwards (ref. 34)	Questionnaire	Record of inhabitants involved	Twice	45 min	Pretest and posttest	Established	Established	15	Value preferences	Background data
Impression Formation Test	Cognitive functioning	Bryson and Driver (ref. 35)	Behavioral test	Change score	Twice	20 min	1/2 pretest and 1/2 during test	Against control group	Against predictions	1	Level of internal cognitive	Background data and with GSR arousal to complex stimuli
GSR Arousal to Complex Polygons	Physiological cognitive	Bryson and Driver (ref. 35)	Behavioral test	Change score	Twice	20 min	1/2 pretest and 1/2 during test	Against controls	Tentatively established	1	Level of Arousal to complex stimuli	Background data with IFT
Complexity of Leisure Time Use	Leisure time	Original	Observer rating	Daily variation, corrections	Once a day	During leisure time	During test	Odd against even days	Not necessary	1	Leisure time use	Mood, attitude, EMG
Willingness to volunteer again	Evaluative	Original	Interview debrief	Habitat record	Once	5 min	Posttest	None	None	1	Willingness to return to habitat	Background data
Amount of Food Eaten	Self-maintenance	Original	Observer rating	Daily variation, corrections	Daily	During mealtimes	During test	Odd against even days	Pre- and Post-food weigh-in	1	Amount of daily food consumption	Mood, attitude, leisure activity record
OART/LRC Psychomotor Task	Psychomotor	Benjamin Franklin Gulf Mission (ref. 17)	Behavioral test	Daily variations, correlations	Daily	20 min	Pretest, during test, posttest	Odd against even days	None	1	Skill at complex psychomotor task	Mood

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parameter the experimenter wishes to include; in analyzing the data, temporal patterns that are not readily apparent to the subject in retrospect can be put together. The resulting data can be correlated with time-locked recording of physiology, overt behavior, or other covert behaviors. Another advantage is that immediate responses to a checklist are less susceptible to social desirability and other contaminating sets than are retrospective reports (ref. 36). The checklists are disadvantageous in this particular research context because they contain measures of up to 12 mood factors that require extensive data analysis. Also, the report of any subject must be taken on faith and is simply the result of haphazard socialization experiences in labeling types of internal organization. Another disadvantage is that they do not give clear guidance concerning how adjustment to the environment can be improved. However, mood checklists are currently among the best of the indexes now available; this is indicated by the findings of Radloff and Helmreich (ref. 14): "of self-report measures, the mood checklist is the most reliable, most easily administered and the most valid index of individual response to stressful situations. The method of collection (by checking a large number of adjectives) is probably less threatening than any other approach and thus elicits less defensiveness and denial. It would certainly seem warranted to continue to collect mood checklist data in field studies of stress wherever feasible." The mood checklist and other relevant information about this test are included in tables 2-2 through 2-7.

Attitude measurement is another proven useful technique in habitability assessment. The previously mentioned work by Moos and Houts (ref. 6) shows that attitudes toward a habitat are clearly correlated with other behavioral tendencies in the habitat. There are a number of possibilities in the attitude measurement realm. As a part of this study, the Moos Ward Atmosphere Scale has been varied by rewording items so the test applies to habitats in general (see Appendix B). Although this scale probably is a useful approach, some version of the Osgood Semantic Differential (also used in studies by Moos) is probably most pertinent for attitude assessment. The Semantic Differential is brief, can be given repeatedly, and tends to elicit undefended and nonstereotyped responses because the scoring of the test is not obvious to the subject (see Appendix B). This test has been used successfully with subjects as young as four years old; a version could be created that is simple, short, and palatable. It is recommended that the Semantic Differential be combined with a utility analysis (ref. 37) so that subjects are not only asked their attitudes toward various aspects of the habitat, but also asked to rate the degree of relationship they perceive between each rated aspect and such goals as overall mission success, maintaining psychological stability throughout the mission, or maintaining optimum crew performance. Change in perception of these relationships as time passes in the isolated environment should be as important a question as change in the evaluative aspect of attitudes measured by the Semantic Differential. Again, such measurement is relatively simple and can be done in a short period of time. Attitude measurement is clearly an important part of habitability assessment. However, it is disadvantageous because it does not reveal the internal dynamics of adjustment as well as some other measures. Also, it can be annoying to subjects after many repetitions, and attitude reports can be biased by the desire of the testee to create a favorable impression of himself for the benefit of the experimenter.

TABLE 2-2

A SHORT FORM OF THE MOOD ACL

Each of the following words describes feelings or mood. Please use the list to describe your feelings at the moment you read each word. If the word definitely describes how you feel at the moment you read it, circle the double check (vv) to the right of the word. For example, if the word is relaxed and you are definitely feeling relaxed at the moment, circle the vv as follows:

relaxed vv v ? no. (This means you definitely feel relaxed at the moment.)

If the word only slightly applies to your feelings at the moment, circle the single check v as follows:

relaxed vv v ? no. (This means you feel slightly relaxed at the moment.)

If the word is not clear to you or you cannot decide whether or not it applies to your feelings at the moment, circle the question mark as follows:

relaxed vv v ? no. (This means you cannot decide whether you are relaxed or not.)

If you definitely decide the word does not apply to your feelings at the moment, circle the no as follows:

relaxed vv v ? no. (This means you are definitely not relaxed at the moment.)

Work rapidly. Your first reaction is best. Work down the first column, then to the next. Please mark all words. This should take only a few minutes. Please begin.

angry vv v ? no
clutched up vv v ? no
carefree vv v ? no
elated vv v ? no
concentrating vv v ? no
drowsy vv v ? no
affectionate vv v ? no
regretful vv v ? no
dubious vv v ? no
boastful vv v ? no
active vv v ? no
defiant vv v ? no
fearful vv v ? no
playful vv v ? no
overjoyed vv v ? no
engaged in thought vv v ? no
sluggish vv v ? no

kindly vv v ? no
sad vv v ? no
skeptical vv v ? no
egotistic vv v ? no
energetic vv v ? no
rebellious vv v ? no
jittery vv v ? no
witty vv v ? no
pleased vv v ? no
intent vv v ? no
tired vv v ? no
warmhearted vv v ? no
sorry vv v ? no
suspicious vv v ? no
self-centered vv v ? no
vigorous vv v ? no

(see refs. 18 and 19)

TABLE 2-3

MATCHED AXES IN FIVE GREEN-NOWLIS ANALYSES

Factor and Variable *	Highest Loadings in 5 Analyses	Source of Data: I Pre- 3 + 4 + 5	II Pre-2	III Post-2 Hoax	IV Post-3 Comedy	V Post-4 Nuremberg
A, Aggression		Axis No. 1	No. 6	No. 4	No. 5	No. 6
defiant	AAAAA**	30***	50	43	39	56
rebellious	AAAAA	34	44	52	35	54
angry	-gAABA		37	37		39
grouchy	bAAbA		43	30		43
annoyed	iAA-cA		33	44		50
fed-up	aAAtA	14	37	46		45
B, Anxiety		Axis No. 2	No. 9	No. 1	No. 1	No. 3
clutched up	BBBbB	44	32	52	20	35
fearful	BBBbB	40	26	45	18	43
jittery	bBBtB	21	42	37		36
C, Surgency		Axis No. 3	No. 3	No. 5	No. 3	No. 2
carefree	CCCCC	47	36	47	52	33
playful	CCCCC	38	44	47	43	50
witty	CCcCC	48	38	28	32	35
lively	CckCC	33	24		36	30
talkative	CC-hCc	44	30		32	22
C, Elation		Axis No. 8	No. 8	None	None	None
elated	DDccC	45	30			
overjoyed	DDcCC	45	45			
pleased	DD-aCC	40	30			
refreshed	Ddccc	32	23			
E, Concentration		Axis No. 4	No. 4	No. 9	No. 4	No. 1
attentive	-fEEE-n		46	35	58	
earnest	EEeE-n	43	37	24	42	
serious	EEEe-n	58	44	32	28	
comtemplative	EEe-cE	47	37	18		47
concentrating	EEEEe	44	59	36	47	28
engaged in thought	EEEee	51	37	31	25	23
intent	EEEEe	33	46	45	50	24
introspective	Eee-cE	41	23	21		39

* Only 49 of 96 variables are included in this table.
** The letters indicate the factor on which the variable had its highest loading in each analysis. Capital letters indicate values = or > than 0.30; other letters indicate values below 0.30.
An ampersand (&) indicates the variable had loadings = or > 0.30 on two axes in the same matrix.
*** Decimals omitted. The values presented are the highest loading each variable had in each rotated solution.

TABLE 2-3 (Continued)

Factor and Variable	Highest Loadings in 5 Analyses	Source of Data				
		I Pre- 3+4+5	II Pre- 2	III Post-2 Hoax	IV Post-3 Comedy	V Post-4 Nuremberg
F, Fatigue		Axis No. 5	No. 5	No. 2	No. 6	None
drowsy	FFFFg	55	52	38	50	
dull	FFFxx	32	66	30	not used	
sluggish	FFFfg	48	49	37	29	
tired	FFFFg	53	52	33	49	
G, Social Affection		Axis No. 6	No. 2	No. 7	None	No. 5
affectionate	GGGfG	52	51	50		45
forgiving	GGgfG	48	39	21		34
kindly	G-AgeG	46		28		59
warmhearted	GGGeG	43	44	39		49
H, Sadness		None	No. 7	No. 6	No. 2	No. 7
regretful	bHHhH		35	41	28	45
sad	fHHhH		39	44	21	33
sorry	bhHhH		26	39	25	44
I, Skepticism		Axis No. 9	No. 1	None	No. 9	No. 8
dubious	IiF-cB&I	32	26			43
skeptical	IIFIB&I	41	39		52	45
suspicious	IafiB	38			19	(27)
J, Egotism		Axis No. 7	None	No. 8	None	No. 9
egotistic	JbJA-h	45		43		
self-centered	E&JBJeJ	46		49		56
aloof	eajAJ	(22)		17		30
boastful	JaJAj	34		36		23
K, Vigor		None	None	No. 3	None	None
active	-f-fK-fn			31		
energetic	-f-fK-fa			30		
vigorous	-f-fK-fa			41		
N, Nonchalance		None	None	None	No. 7	No. 4
leisurely	FccNn				31	28
nonchalant	CCCNN				37	39

(from ref. 18)

TABLE 2-4

FACTORS TENTATIVELY MATCHED ACROSS 15 STUDIES

Factor	5 Green-Nowlis Analyses	2 Green-Nowlis Replic.	2 Borgatta Replic.	2 Thayer Analyses	3 McNair-Lorr Analyses	Reimanis	Matches Tests
A, Aggression	5 Yes	2 Yes	2 Yes	2 Yes	3 Yes	1 Yes	15/15
B, Anxiety	5 Yes	2 Yes	2 ?	2 Yes	3 ?	1 Yes	10/15 + 5 ?
C, Surgency	5 Yes	1 Yes	No Test	No Test	No Test	No Test	6/7
D, Elation	2 Yes	2 No	2 ?	1 Yes	No Test	1 Yes	4/12 + 2 ?
E, Concentration	5 Yes	2 Yes	2 Yes	2 Yes	1 Yes 2 No Test	1 ?	12/13 + 1 ?
F, Fatigue	4 Yes	2 Yes	2 Yes	2 Yes	3 Yes	1 Yes	14/15
G, Social Affection	4 Yes	2 Yes	2 Yes	1 Yes	1 Yes 2 No Test	1 No	10/13
H, Sadness	4 Yes	1 Yes	2 ?	2 Yes	3 ?	1 ?	7/15 + 6 ?
I, Skepticism	4 Yes	No Test	1 ?	2 Yes	No Test	No Test	6/9 + 1 ?
J, Egotism	3 Yes	1 Yes 1 ?	1 Yes	2 Yes	No Test	1 ?	7/12 + 2 ?
K, Vigor or General Activation	1 ?	2 No	No Test	2 Yes	3 Yes	1 Yes	6/13 + 1 ?
N, Nonchalance or General Deactivation	2 ?	No Test	No Test	2 Yes	No Test	No Test	2/7 + 2 ?

(from ref. 18)

TABLE 2-5

SOCIAL DESIRABILITY OF TEN MOOD FACTORS

Factor	Males	Females
Social Affection (G)	6.0	6.3
Concentration (E)	5.9	6.0
Pleasantness (D)	5.3	5.5
Surgency (C)	5.1	5.3
Depression (H)	3.0	3.0
Anxiety (B)	2.5	2.4
Fatigue (F)	2.5	2.6
Skepticism (I)	2.4	2.4
Aggression (A)	2.2	2.0
Egotism (J)	2.0	2.0

(from ref. 18)

TABLE 2-6

DIFFERENCE SCORES FOR INDIVIDUAL VARIABLES IN TWELVE FACTORS IN SIX DIFFERENT EXPERIMENTAL SESSIONS

Factor	One: Lincoln	Two: Hoax	Three: Comedy	Four: Nuremberg	Five: Operation	Six: Contest
A, Aggression						
defiant	-.06	.34	.02	.78	-.11	.08
rebellious	-.14	.30	.08	.69	-.11	.01
angry	-.03	.41	-.13	1.56	.00	.08
grouchy	-.24	.44	-.29	.25	-.12	.15
annoyed	-.06	.61	-.38	1.06	.03	.10
fed up	-.23	.41	-.33	.68	-.14	-.01
(Mean)	(-.13)	(.42)	(-.17)	(.84)	(-.08)	(.07)
B, Anxiety						
clutched up	-.16	.00	-.05	.48	.29	.13
fearful	.01	.02	-.01	.74	.26	.14
jittery	-.15	-.18	.04	.40	.32	.05
(Mean)	(-.10)	(-.05)	(-.01)	(.54)	(.29)	(.11)
C, Surgency						
carefree	-.37	-.10	.59	-.99	-.62	-.36
playful	-.45	-.18	.73	-1.06	-.60	-.43
witty	-.44	-.22	.38	-.94	-.62	-.42
lively	-.19	-.26	.64	-.73	-.12	-.30
talkative	-.25	-.02	.34	-.68	-.22	-.40
(Mean)	(-.34)	(-.16)	(.54)	(-.88)	(-.44)	(-.38)
D, Elation						
elated	.00	-.24	.74	-.78	-.32	-.23
overjoyed	.06	-.21	.95	-.61	-.29	-.18
pleased	.09	-.47	.84	-1.15	-.36	-.16
refreshed	-.03	-.40	.64	-.78	-.31	-.27
(Mean)	(.03)	(-.33)	(.79)	(-.83)	(-.32)	(-.21)
E, Concentration						
concentrating	.05	-.29	-.30	.45	.30	.15
engaged in thought	.20	-.21	-.43	.90	.44	.24
intent	-.01	-.24	-.10	.35	.22	.00
attentive	.00	-.31	-.04	.39	.30	.06
earnest	.07	-.34	-.25	.24	.12	.04
serious	.19	-.26	-.80	.82	.49	.18
contemplative	.36	-.22	-.48	.68	.41	.13
introspective	.05	-.11	-.29	.28	.20	.01
(Mean)	(.11)	(-.21)	(-.30)	(.46)	(.27)	(.08)

(from ref. 18)

TABLE 2-6 (Continued)

Factor	One: Lincoln	Two: Hoax	Three: Comedy	Four: Nuremberg	Five: Operation	Six: Contest
F, Fatigue						
drowsy	.03	.24	-.29	-.11	-.08	.33
dull	-.11	.24	-.24	-.06	-.11	.14
sluggish	-.05	.23	-.24	-.04	-.08	.24
tired	-.08	.34	-.30	-.01	-.10	.26
(Mean)	(-.05)	(.26)	(-.27)	(-.06)	(-.09)	(.24)
G, Social Affection						
affectionate	-.15	-.23	.16	-.61	-.23	-.20
forgiving	.01	-.23	-.08	-.60	-.05	-.24
kindly	.05	-.39	.20	-.70	-.09	-.20
warmhearted	.11	-.39	.31	-.74	-.22	-.26
(Mean)	(.00)	(-.31)	(.15)	(-.66)	(-.15)	(-.23)
H, Sadness						
regretful	.22	.22	-.18	1.17	.09	.14
sad	.29	.08	-.22	1.28	.13	.05
sorry	.21	-.01	-.08	1.24	.14	.06
(Mean)	(.24)	(.10)	(-.16)	(1.23)	(.12)	(.08)
I, Skepticism						
dubious	-.37	-.02	-.26	.23	-.07	.13
skeptical	-.40	.07	-.35	.19	.02	.12
suspicious	-.22	.10	-.18	.47	.01	.11
(Mean)	(-.33)	(.05)	(-.29)	(.30)	(-.01)	(.12)
J, Egotism						
egotistic	-.36	-.02	-.05	-.34	-.20	-.03
self-centered	-.23	-.01	-.14	-.27	-.15	-.02
aloof	-.11	-.61	-.13	-.20	-.18	-.08
boastful	-.22	-.01	.18	-.36	-.18	-.15
(Mean)	(-.23)	(-.16)	(-.04)	(-.29)	(-.18)	(-.07)
K, Vigor (?)						
active	-.31	-.26	.37	-.23	-.19	-.05
energetic	-.11	-.33	.41	-.24	-.22	-.28
vigorous	-.18	-.21	.39	-.18	-.14	-.12
(Mean)	(-.20)	(-.27)	(.39)	(-.22)	(-.18)	(-.15)
N, Nonchalance						
nonchalant	-.26	-.34	-.12	-.97	-.53	-.30
leisurely	-.47	-.24	-.15	-.94	-.60	-.30
(Mean)	(-.37)	(-.29)	(-.14)	(-.96)	(-.57)	(-.30)

(from ref. 18)

TABLE 2-7

PERCENTAGE OF SIGNIFICANT CORRELATIONS BETWEEN MOOD FACTOR SCORES AND 45 SUBTESTS OF THE MMPI, CATTELL 16 PF TEST, AND THREE GUILFORD INVENTORIES

	MMPI	Cattell	Guilford	Total
2nd MACL	25	10	13	16
Next to last MACL	23	15	25	21
Mean daily MACL	20	09	15	14
Standard Deviation of daily MACL	20	10	25	18
Total	22	11	19	17

(from ref. 18)

Content analysis of guided diaries is another promising approach to the study of habitability. Guided diaries have the advantages that they give subjects a chance to express things in their own way and emphasize or highlight various observations that are of particular importance to them. Content analysis systems can be worked out by hand for such diaries (refs. 38 and 39), or they can be subjected to various computerized content analysis systems such as the General Inquirer system (ref. 40). The latter system is a flexible one and has been shown to be sensitive to long-term effects of altered environments in African field work volunteers (ref. 41). Disadvantages of such methods are that they do not always cover information the experimenter needs and they are easily susceptible to response sets or to unintentional desires of the subject to create a certain impression of himself. Furthermore, the relevance of scores on the categories chosen to the problem under study is not always clear. Examples of guided diary instructions are presented in the following three paragraphs.

> Please make a record of any inconveniences, accidents, or habitat-caused problems that occurred to you today during your stay in Tektite II. For example, are there ways the habitat could have better supported mission success, crew compatibility, or the quality of life on board Tektite II? Do you have any suggestions on ways that these problems could be overcome in redesigning the habitat? Use the space below as you need it.
>
> Please make a record of all habitat duties, maintenance work, repair work, and other kinds of work activities that you engaged in while in Tektite II during this day. Are there ways in which the habitat could have been more supportive to you in doing this work? If so, please comment.
>
> Please include in the space below any further evaluations that you might have of the habitat in which you are now residing. Information on such things as the quality of the food, the quality of your sleeping, any problems in hygiene, any observations or comments on leisure time and recreation, and general reactions you have had to living in Tektite II would be pertinent.

The other technique for measuring covert response would require extensive training and testing of the subject in discrimination and report of his covert behavior. Such trained subjects could then be used in giving particularly accurate reports on the effects of various environments on their internal functioning. Our proposal of this particular technique for gathering self-report during confinement in habitats is done with the understanding that the empirical study of awareness has been psychology's most vexing and challenging problem (refs. 42, 43, and 44). A widely cited body of evidence has been accumulating recently that biofeedback training techniques may be a considerable step forward in this area because, more so than any other techniques known of, biofeedback helps to make the study of covert psychological response amenable to careful scientific scrutiny. With display devices that signal the subject whenever selected physiological patterns are present in the subject's physiological processing, such subjects have been trained successfully to learn to discriminate variations in their EEG alpha rhythm (refs. 45 and 46), heart rate (ref. 47), muscle tension (ref. 23), physiological sleep stages (ref. 48), and numerous other internal events.

The research done so far has occurred in various laboratories that were interested in some one specific physiological process. However, preliminary evidence with subjects trained to discriminate several of their on-going physiological processes indicates that such information could be used to build, for the first time in psychology, maps of the subjective space in an individual associated with internal events (ref. 49). Such maps would be different from the actual somatic events themselves; for example, a relaxation dimension identified in preliminary research seems to include elements of heart rate slowing, increased EEG alpha activity, blood pressure lowering, decrease in frontalis EMG level, decrease in spontaneous electrodermal activity, and increase in vasodilation. Other dimensions could emerge and be given more precise definition by empirical multi-variate analysis of the reports of subjects trained in discriminating a number of these processes. It would certainly be interesting to compare various habitats on the relaxation dimension alone. As such trained subjects became available and the relevant empirical dimensions of internal awareness were defined, the subjects could be used for accurately identifying the internal effects of a wide variety of potential habitats, including new car designs, various urban areas, new underwater submersibles, and new spacecraft.

Tangentially, such research could be useful beyond its assessment function; it actually could lead to improved adaptive potential to longterm isolated habitats. The literature on the problem strongly suggests that training in discrimination of physiological processes leads to a substantial amount of voluntary control over these processes. This was shown as early as 1901 in the pioneering work of Bair (ref. 49), and is shown again in more recent reports by Donelson, Kamiya, Budzynski, and others. Subjects who have undergone such training are able, on command or spontaneously of their own volition, to make deliberate alterations in those physiological processes they have learned to discriminate. Presumably, such training would allow men to tolerate higher amounts of stress without succumbing to physiological disequilibrium and would allow them to relax more quickly and efficiently after tension-inducing situations. In support of this position, Weybrew (ref. 50) has found that submariners with naturally fast autonomic recovery after stress adjust better to life in a submarine than do those with slower autonomic recovery indexes. Biofeedback training simply would allow voluntary and effective control over this previously involuntary reaction tendency. As Larson states,

> "Perhaps the most important implication of a phenomenological perspective on habitability is the notion that crew personnel may be 'trained' in such a manner that their response to behavior constraints and fulfillment of expectations will lead to a perception of heightened (or maintained) habitability of their area or space." (ref. 1)

The biofeedback training procedure is recommended here apart from its possible role in helping to improve the habitability of isolated confines. For assessment purposes, it has the strong advantage that it is the type of subjective report that is most amenable to scientific verification. Subjects can and would be trained to the point that they could discriminate internal processes accurately without receiving further feedback. On the basis of previous research (ref. 23), it is estimated that this would take an average of six one-hour sessions per physiological system trained. The disadvantages of this

assessment procedure are the newness of the technique and the length of time required to complete training to adequate discrimination-ability standards.

On-Going Observation Assessment Techniques

Observation of on-going behavior in real-life situations, either direct or via radio or TV monitoring, is the assessment procedure that has been tried for the longest period of time in research on understanding and ultimately predicting reactions to nonlaboratory situations. Early attempts by Goodenough (ref. 51); Thomas (ref. 52); Thomas, Loomis, and Arrington (ref. 53); Arrington (ref. 54); and Brunswik (ref. 55) indicated the importance of the problem and that a solution could be found. More recently, significant studies by Barker and Wright (refs. 56 and 57), Barker (ref. 58), Zinner (ref. 4), and Soskin and John (ref. 38) have shown that (1) selected natural environments do in fact have powerful effects on their inhabitants, (2) these effects are measurable, and (3) progress can be made using the observation technique despite the problem of observer influence on the observed. In some ways, the observation technique is less demanding on subjects: no checking, writing, or reporting is necessary; but if not handled well and not limited in some way, constant observation can be more intrusive and disturbing than other techniques. Two excellent reviews of the promise, possible techniques, and difficulties in observations of real-life situations have been done by Fiske (ref. 59) and Barker (ref. 60).

Recommended observation techniques include an observer rating of complexity of leisure time use, an observer record of amount of food eaten, an observer rating of social intercourse level, and an electronic instrument record of location and frequency and length of use of various facilities. It is recommended that direct observations of subjects be limited to certain times during the day; but that there be constant electronic "bugging" of various areas for a full-time use-of-facilities record.

Observers would monitor behavior for some agreed upon time each day, perhaps one to two hours during dinner and subsequent leisure time, at the same time or times each day. Of particular interest would be observations of the complexity and constructiveness of leisure time use. An appropriate rating scale of all possible activities would have been developed previously and would be used for this purpose. An example of such an observer-rating scale is shown in fig. 2-1. From a review of the literature on isolated habitats, it is believed that leisure time use is a particularly distinguishing feature of various habitat types. It is predicted that constructiveness of leisure time use will be positively correlated with other measures of successful habitability. This is discussed in more detail under functions of recreation and leisure time use in Section 5 of this report.

Mealtimes, particularly suppertime, seem to be a good time to monitor behavior and to make other observational records of behavior. One such observation simply could be the amount of food eaten. This again is a variable that

LEISURE TIME USE RECORD

INSTRUCTIONS: Please keep a record of any leisure activity spent in Tektite II using the log below. Leisure activity includes time spent that is not for the purposes of work, hygiene, preparing and eating regular meals, repair and maintenance, mission-relevant communication, sleeping, or housekeeping. All loafing, entertainment, snacking, nonmission-relevant conversation, games, nonmission relevant reading, and so on (see below) should be included. Time should be kept to the nearest 5 min and A.M. or P.M. should be specified.

Man ID	Time		Date	Leisure Time Activity Code	Source of Equipment	Specify Nature of Activity	Type of Leisure Activity Scale
	From	To					

Leisure Time Activity Code

1. Exercise
2. Loafing
3. Hobbies
4. Snacking or drinking
5. Reading
6. Listening to music or taped readings
7. News and current events
8. Other radio or TV
9. Learning
10. Writing, drawing, and painting
11. Playing musical instruments
12. Games (cards, chess, etc.)
13. Talking and conversation
14. Unknown

Source of Equipment Mode

1. Leisure time kit
2. Personal preference kit
3. Video display
4. Others

Specify more precisely in writing the nature of the activity whenever this is possible (e.g., what film is being watched, what game is being played, etc.); also please specify approximate location.

Type of Leisure Activity Scale

1. Loafing, resting, and whiling the time away
2. Passively watching films, TV, or doing light reading of little or no informational value
3. Playing cards or other light games with others, writing letters, light conversation, listening to news or other radio or TV of educational or informational value
4. Exercising, constructive reading, conversation oriented toward complex topics, careful listening to music or voice tapes, playing highly involving games, such as chess, with others or with computer
5. Constructive activity oriented toward self-improvement, e.g., working with audio-visual programs, doing heavy reading, or engaging in creative expression in art, writing, or making music.

Figure 2-1. Leisure Time Use Record

seems to vary considerably in different isolated habitats, and lowered food intake to some degree seems to be a sign of less successful habitability. There is an alternative to direct observation; the cook could be asked to keep a record of the amount of food consumed each day. However, it presently appears advantageous to keep records of how much food is consumed by each man separately and what liquid accompanied the food consumption. For these reasons, direct visual and auditory monitoring is recommended. (See fig. 2-2.)

A record of social intercourse level during some specified event each day would be desirable, and since suppertime would give an opportunity for social intercourse, depending on crew schedules, this would be a likely time to make such observations. The Interpersonal Diagnostic Report (ref. 21) is the most broad-based of the many available observational systems for rating social interaction (Appendix C). Definition of the social behaviors to be expected in good and poor habitability environments is a difficult task. More constriction in the range of social behaviors than is normally the case would be expected in the isolated habitat, but the degree of constriction that should be interpreted as desirable is still an unanswered question.

Finally, a location record (fig. 2-3) and use of selected facilities record (figs. 2-4 and 2-5) would be kept constantly throughout the experimental period in the isolated habitat. The location record would give an overall index (for various averaged times of day and for each individual complete day) of the amount of time spent in food areas, sleep areas, work areas, and areas where there were other crew members. Various instruments and facilities of interest also would be "bugged;" for example, the bed, work instruments, communication facilities, leisure time facilities, and hygiene facilities would be equipped with microphones.

Analysis of the observational records will proceed in a manner quite similar to the analysis of the self-report data; the same kinds of reliability checks will be performed; temporal covariation with other tests will be made during the experimental period, and relationship of means for the duration of the period to the pre- and post-tests will be foci of the analytic endeavor.

On-Going Physiological Assessment Techniques

The development of multi-level monitoring of overt, covert, and physiological activity over time appears to be a practical research endeavor because of current improvements in psychological testing and physiological tracking (ref. 19). Such a habitability monitoring system could provide information on the full hierarchy of behavioral adjustment processes to a given environment and could entail little disruption of the subject's on-going activity. Although there are a wide variety of physiological processes that could be of interest in such a paradigm, presently only two are suggested--sleep and frontalis EMG level.

There is a growing body of evidence to indicate that sleep pattern disruption frequently precedes psychological breakdown (ref. 61). There also is some evidence to indicate that normal adjustment to a new and unusual environment involves increase in REM or dream time.

Meal Behavior Record

Date:______________________

ID of eater	ID of cook	ID of server	ID of clean-up man	Time		Meal code	Size code	Rate code	No. of companions	Percent of time conversing	Location code
				From	To						

Time: Should begin with seating for meal and end with leaving meal eating area

Meal code:
1. breakfast
2. lunch
3. supper
4. snack
5. other meal

Size code:
1. very small
2. small
3. average
4. large
5. very large

Rate code:
1. eats slowly
2. eats moderately
3. eats fast

Location code:
1. sleep area
2. waste-management area
3. experimental area
4. wardroom

The number of companions is the number of men eating at the same time as the man being coded. Estimate percent of time spent conversing to the nearest 10 percent (e.g., 0%, 50%, 100%).

(adapter from ref. 13)

Figure 2-2. Meal Behavior Record

Location Record

Using either the electronic bugs or the video monitoring system, keep a record of the time spent in each of the four areas of the habitat and whether or not the subject was interacting with others at the time. This record will have to be updated frequently, particularly at each time a subject moves from one compartment to another.

Date______________________

Man ID	Time of ingress	Compartment code	Social interaction	Time of egress

Compartment code:

1. Sleep area
2. Waste management area
3. Experimental area area
4. Wardroom

Social interaction:

1. Did occur
2. Did not occur

Figure 2-3. Location Record

(adapted from ref. 13)

Electronically monitored facilities usage

Date______________________

Man ID	Facilities Code	Time From	To

Facilities Code:

1. Bed
2. Head
3. Stove
4. Communication facility

Figure 2-4. Electronically Monitored Facilities Usage Record

Communication Activity with Habitat Nonresidents

Date________________________

This should be filled out for each communication between residents of the habitat and anyone outside the habitat

Man ID (Resident)	Time		Initiator code	Specify non-habitat communicator	Specify communication mode	% of conversation about operation
	From	To				

Initiator Code:

1. Topside
2. Resident of habitat

For percent of conversation devoted to operational as opposed to other topics, include medical reports, repair and scheduling problems, maintenance, and other procedural topics directly related to the mission and its success as operational; include discussion of the news, non-mission-relevant weather, non-mission-relevant social activity, etc. in non-operational time. Estimate to the nearest ten percent (e.g., 0 percent operational, 10 percent, 100 percent)

(adapted from ref. 13)

Figure 2-5. Communication Activity with Habitat Nonresident Record

Thayer has done some preliminary research on the relationship of sleep patterns to moods (ref. 24), but this research was not done in isolated environments. Such research could be advanced when done in an environment in which control for exposure to highly different kinds of environmental stimuli was not necessary; it would be particularly feasible in the situation requiring repeated mood and attitude measurement. Such research offers the promise of uncovering information about the role of sleep in adjusting to a special habitat (fig. 2-6). However, different sorts of isolated habitats seem to foster different sleep patterns. For example, SEALAB II (ref. 14) and the Benjamin Franklin Submersible Gulf Stream Mission appear to have had gradually deleterious effects on ability to sleep. According to Dement's theory of sleep (ref. 61), such patterns should be correlated with increasingly unsuccessful habitability adjustment to the environment. Because using sleep patterning as an index of habitability is possible and because it can give clues as to incipient psychological breakdown, monitoring of sleep during any stay in an isolated habitat presently appears to be a promising and meaningful research activity.

There is a growing body of evidence to indicate that the electromyographic level of the frontalis muscle is closely related to feelings of tension and anxiety, and that high amounts of such muscular tension can lead to headache and other signs of behavioral impairment in dealing with the environment (see ref. 25). Thus, it would be meaningful to regularly monitor frontalis EMG level during time spent in an isolated habitat, particularly if such observations were time-locked with behavioral observation and self-report data (fig. 2-7). It is predicted that high EMG levels would be correlated with indexes showing poor habitability adjustment. One technique for making such recordings is to train subjects to attach the necessary electrodes themselves at the same time each day and then sit quietly with the electrodes on for 20 min before removing them. The data analysis procedure for physiological measurements would be similar to the procedures already discussed for self-report and behavior observation. Similar reliability checks would be done, variations from day to day that correlated with daily fluctuations in other variables would be searched for, and overall means would be related to pretesting and posttesting.

MEASUREMENT OF HABITABILITY BY EVALUATION OF THE PROPERTIES OF THE HABITAT ITSELF

As research progresses, better and better predictions will be made about the habitability of an isolated environment simply by examining the spaces and facilities of interest in the given environment without necessary long stays in that environment. Two tests have been designed that need to be evaluated for their predictive power.

Larson (Appendix A) has pointed to the importance of careful analysis and definition of the environment under study. As he further states: "Reduced to simplest terms, then, the current concept of habitability is one that posits habitability as the result of how an environment is supportive to an individual's needs for behavior in areas of duty, leisure, sleep, and body function. An area of space that allows fulfillment of behavioral requirements within the system of

Percent time REM sleep

Date________________________

Man ID	Overall sleep time		Stage-1 sleep	Stage-2 sleep	Stage-3 sleep	Stage-4 sleep
	From	To				

Polygraph printouts and tapes should be preserved; in addition, whenever possible, the night observer should estimate the times spent in the various sleep stages on the record above.

Figure 2-6. Percent Time REM Sleep Record

Frontalis EMG Level

Date________________________

Man ID	Time		EMG level in microvolts
	From	To	

Subjects will have been instructed to attach EMG electrodes at the same time and in the same place each day; then to sit quietly for a period of 20 minutes while EMG level is recorded. If for any reason there is any departure from the agreed upon routine, it will be noted by the observer. Polygraph printouts and tapes will be preserved, but the observer will estimate in microvolts the average EMG level obtained and enter it in the above record.

Figure 2-7. Frontalis EMG Level Data Sheet

constraints with a minimum of disruption or conflict between those constraints, as perceived by the individual, may be said to be habitable."

A set of Habitability Assessment Rating Scales have been designed that list, one by one, all items common to the habitats of western man. The list is divided into six main areas:

Body function and biological support

Task and duty support

Educational and informational support

Recreational and leisure time support

Social and communications support

Miscellaneous items

Some of these areas are divided into various subareas. For example, body function and biological support is divided into (1) food and drink, (2) medicine, (3) hygiene, (4) waste disposal, (5) housekeeping, (6) exercise, (7) sex, and (8) sleep. Under each subarea are listed numerous items that are common to most western habitats and that serve functions in that subarea.

All items are rated in the following six ways:

(1) Does it perform its function well?

(2) How easy is it to maintain?

(3) Is it located conveniently?

(4) Is it comfortable to use?

(5) Is it aesthetically pleasing?

(6) Is it safe?

There is also a space at the end for comments, particularly on any criterion the item does not fulfill in at least an average way. These Habitability Assessment Rating Scales can be used widely for comparing different kinds of habitats. The ratings can be made either by outside trained observers or by inhabitants of the environment itself. The ratings can be averaged into one grand overall habitability figure; they can be broken down according to areas and subareas; they can be broken down according to average ratings on each of the six habitability function criteria; or individual ratings on an item can be used by a designer to spot key trouble spots in a habitat and attempt to improve items according to specific problem areas.

The scales are shown in Appendix D. The scales have been used with success in rating home habitats; they can be of use in spotting dysfunctional tendencies in such habitats. These scales should be used in the study of isolated habitats in two ways. First, an independent group should use the scales to assess the habitat as carefully as they can before it is actually tested in simulated or real conditions. After actual habitation, men who have been confined in the environment for long periods of time should use the scales to evaluate the habitability of the environment when leaving it. It is important to know how the two kinds of ratings agree with each other, what kinds of improvements either set of ratings suggest, and how the ratings relate to other habitability assessment procedures.

Also some sort of rating should be made of the kinds of variety available in any isolated habitat. Variety may be a key problem in the habitability of confined spaces. When confined spaces are compared with normal habitats, there is a marked difference. The isolated environment appears to have less variety in types of sensory inputs, types of motor responses required, and kinds of social contacts and interactions possible. Generally, this is even more true for rhythmic variations over time than for immediately apparent variety; the isolated habitat restricts the variety of perceivable input and shows particularly small amounts of variation in these inputs over time. Scaling procedures of the type termed "ecological psychophysics" (ref. 27; see also refs. 28 and 26) could be done for elegant measurement of such variety; but at this stage, simple ratings of variety in various aspects of the isolated habitat could be called for. Some areas that should be included are leisure time, communications, food, tasks, and room arrangements. As with the Habitability Assessment Rating Scales (HARS), nonresidents and residents could be given the scales, and the results would be related to other habitability assessment scores, and in a similar way to the HARS. (See Appendix D, Part II.)

GATHERING OF BACKGROUND DATA ON EACH PERSON UNDERGOING A PROLONGED STAY IN THE HABITAT

Mischel (ref. 62) has raised some serious questions about whether or not current personality assessment techniques will ever be of real use in predicting behavior. The review by Fiske (ref. 59) points out that psychologists have shied away from the problem of predicting behavior in specified real-life situations. If such opinions are justified, it is not surprising that Weybrew (ref. 31) finds that personality tests have been of little benefit in predicting adjustment to submarine life. Other more informal case histories of adjustment to isolated habitats (ref. 63) help to shed some light on why personality measures may not have been very successful thus far in predicting response to such environments.

However, there can be no doubt that personality will affect habitability in (1) the way in which the individual adjusts to the environment [for support of this statement, see Nowlis and Cohen, (ref. 19)]; and (2) altering the environment according to what sort of people are a part of the habitat to which the individual adjusts. In Larson's model, other people are a part of the environment envelope that influences habitability. The weaknesses of personality tests

are not the only reason they have not proven helpful thus far in predicting real life behavior. Another reason is that the temporal adjustment process to the real-life situation has not itself been an object of study. The Nowlis and Cohen study, one of the few attempts at identifying some of these temporal parameters, indicated that these temporal patterns show highly individual differences and that the temporal patterns are better explained by personality than are the overall mean scores on the behavior measures. Since covert, overt, and physiological activity should be examined according to temporal patterning, a broad-based battery of personality tests given before exposure to the habitat would not only supply background material on the subjects, but might be of use in explaining individual differences in these temporal patterns of adjustment to the habitat. The tests that have been selected here include measures with particularly firm and established reliability and validity. The battery includes a number of tests that have not been tried before in habitability research, but which do have theoretical relevance to the habitability adjustment process as it is presently conceived.

The tests include measures of anxiety, hypnotic susceptibility, level of cognitive functioning, reaction to monotony, sociometric choice, general personality, intelligence, and values. All tests selected for pre- and post-testing are standard ones in the psychological literature, and should be used in their standard form, or whenever possible in alternate forms with high intertest reliability. The tests would include:

Minnesota Multiphasic Personality Inventory

The Edwards Personal Preference Test

The Cattell 16 P.F. Test

The Stanford Hypnotic Susceptibility Scales (Form A for pretesting Form B for posttesting)

The Millers Analogies Test

A Sociometric Workup

A Reaction to Monotony Test

The Impression Formation Test

GSR Arousal to Complex Polygons

The Taylor Manifest Anxiety Test

In addition, crew members would be interviewed at the end of the habitability test, and among other things, asked if they would volunteer for another stint in the habitat. These measures should also be applied after stays in the habitat to check on the possibility that such prolonged stays may make alterations in these aspects of personal functioning. Since small samples would be involved in the initial research, these background tests would be used primarily in an individualized fashion to help explain subject differences in adjustment. If this early work is promising, specific hypotheses would emerge that could be tested as sufficient numbers of subjects are accumulated in the studies.

THE ROLE OF EMPIRICAL MEASUREMENT IN HABITABILITY RESEARCH: CONCLUSIONS

There are a wide array of meaningful approaches to the assessment of habitability in isolated confines. A trilevel assessment procedure during confinement is proposed wherein temporal covariations will be an object of particular study. These three levels assessed during on-going confinement in the habitat under study include (1) self-report on covert behavior, (2) observation of overt behavior, and (3) monitoring of physiological activity. A number of tests have been suggested for accomplishing such assessment. Also, it is recommended that tests be made on various features and qualities of the environment itself.

Finally, it is proposed that individuals selected to stay in the habitat under study for prolonged lengths of time be given a broad-based battery of tests before and after their confinement in the habitat.

SECTION 3

DISCUSSION OF ISOLATED HABITAT DESIGN PARAMETERS

3

DISCUSSION OF ISOLATED HABITAT DESIGN PARAMETERS

The parameters that must be considered in the analysis, design, and evaluation of isolated habitats are complex interactions and overlaps of psychological, physiological, sociological, and physical elements. These interactions are illustrated in fig. 3-1. Superimposed on these interdisciplinary elements are the cultural and individual differences that influence the perception and use of space. Thus, habitability aspects such as arrangement and storage of personal belongings are a function of microculture patterns representative not only of large cultural groups but also of the minute variations in culture that make every individual unique (ref. 64). Discussed in this section are the different parameters that must be considered in the analysis, design, and evaluation of a habitable spacecraft environment.

SPATIAL PERCEPTION

Space seems to be perceived by the senses acting in unison. Studies have shown that when one sense has been blocked, as with blind people, the remaining senses become more active. This is illustrated in the quote from Brodey (ref. 65), "I need to know the currents of this room because the sound is changed by the winds within this space. I must correct for wind. It can blow away the sound image."

Space modulators are those elements that contribute in varying degrees to man's perception of an environment. These items, illustrated in fig. 3-2, must be controlled by the designer before a successful environment can be developed.

At present, very little information and data are available for most of these modulators. Although some (audiovisual) have been thoroughly studied and documented as valid, data on other modulators (personal space and personal territory) are sparse. For space modulators that have been defined only recently (zero-g trafficability and the juxtaposition of positive form and negative space), almost no data are available for use by designers.

In this report, tolerance levels for the space modulators are established from the best available data, and minimum/maximum zones are established when possible. This information is applied to a typical spacecraft habitat. To accurately evaluate the spaces established for crew use, full-scale mockups of representative concepts were constructed. The visual jump associated with the perceptions of an enclosed space from the two-dimensional plan is well known, as quoted recently by Kuhn (ref. 66), "But space itself, being the negative of the material surrounding, the void enclosed in the perceived objects can be apprehended only by bodily being in it." For this study, therefore, following a preliminary evaluation of possible design concepts, mockups were made of the privacy area, wardroom, and hygiene area. Subjects were asked

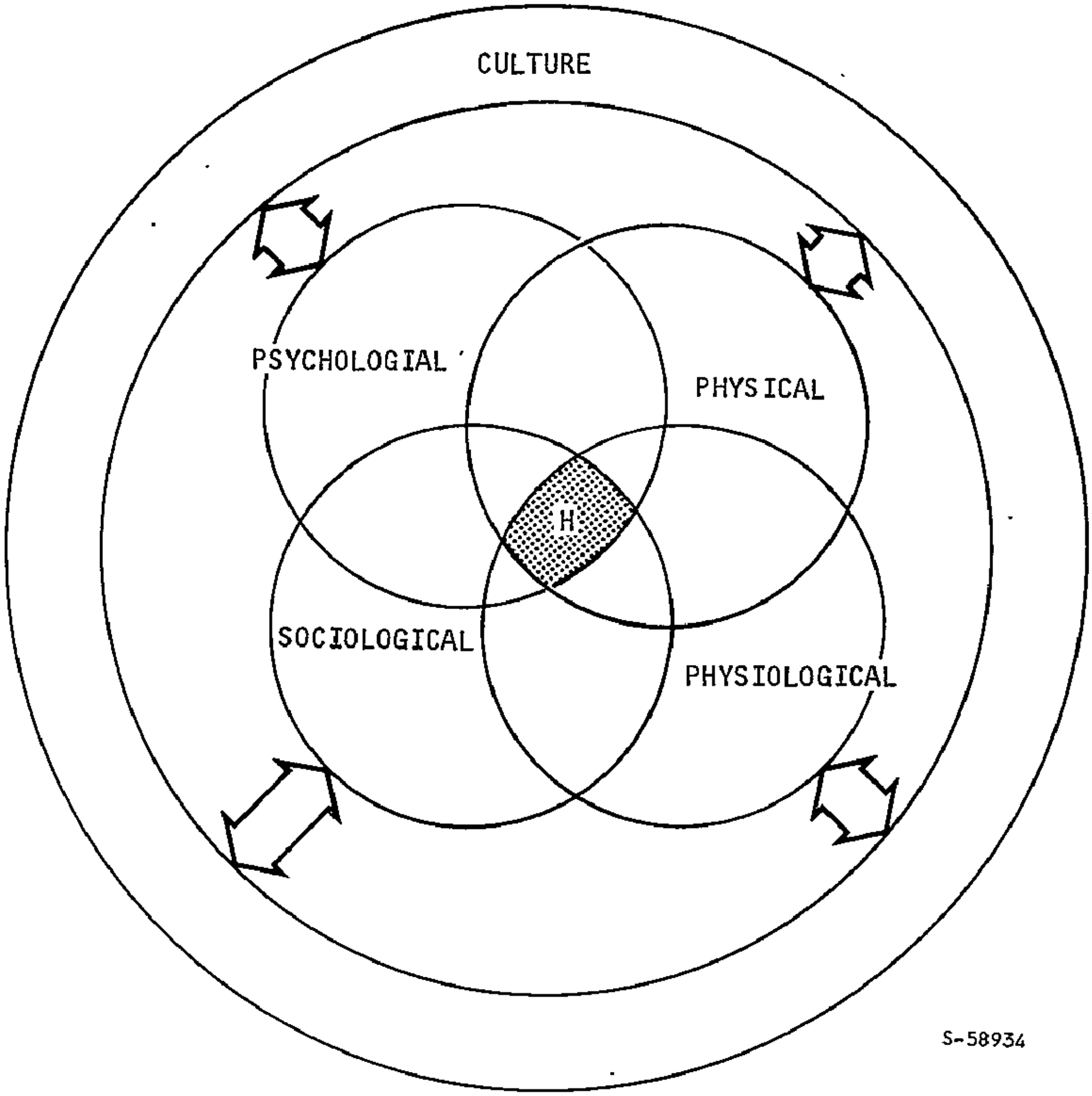

Figure 3-1. Habitability Interactions

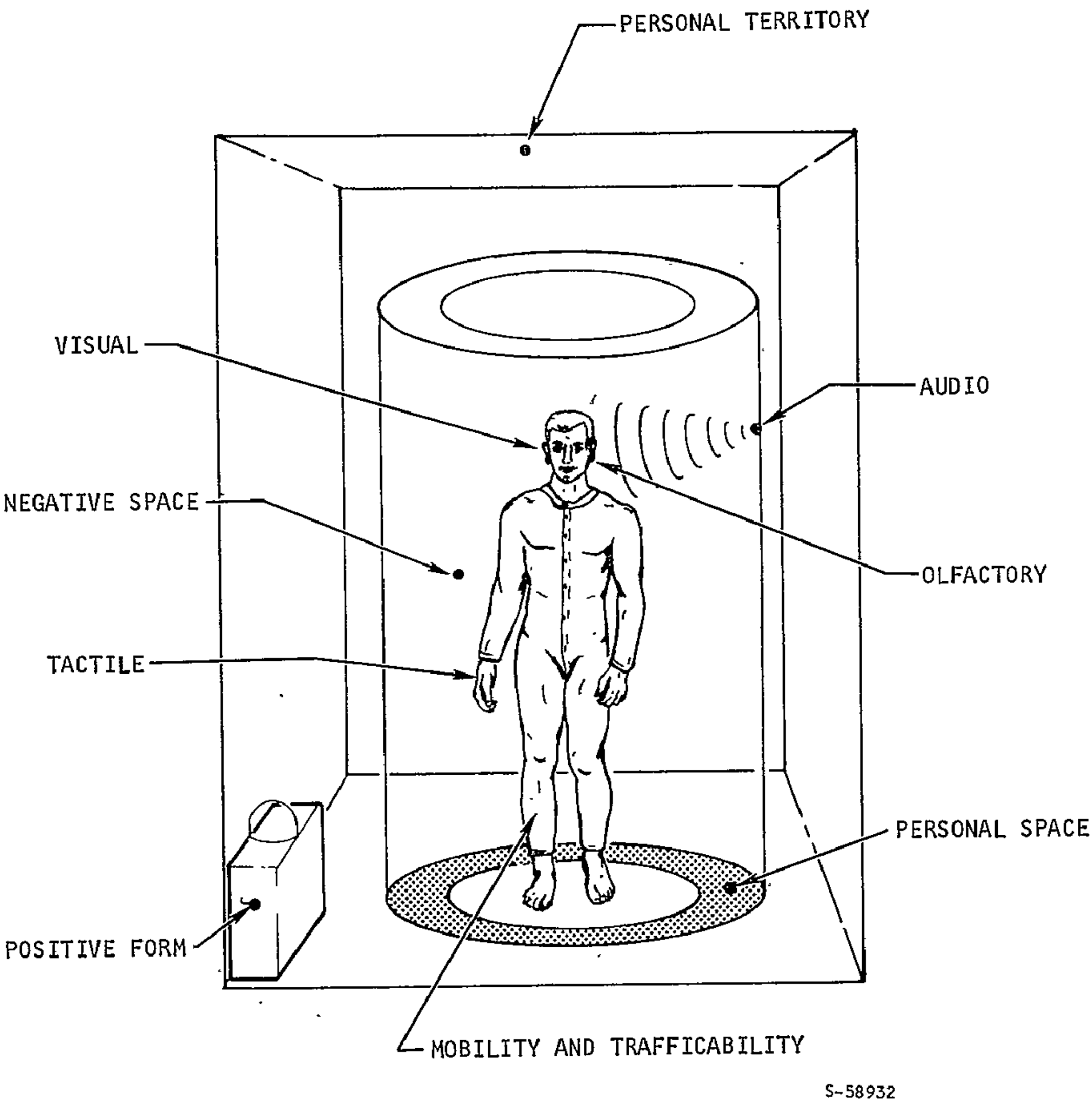

Figure 3-2. Space Modulators

to evaluate the mockups subjectively for their feelings about the amount of space provided. Although this approach did not include the most important factor--time--it was determined to be the most economically feasible method of evaluating and demonstrating three-dimensional space. Changes brought about from the mockup information were incorporated in a 3/4-in. = 1-ft scale model, which was then employed to provide a visual demonstration of the design concepts. The major considerations and limitations for each of the space modulators established are discussed below.

Perceptual and Behavioral Richness

Perceptual richness and opportunity for variety in actions are most difficult to supply in an isolated habitat. Perceptual richness is the sensible variety offered by a given ambient. There appear to be two major aspects of sensible variety: the quantitative aspect of numbers of different things (subsuming complexity); and motion. These concepts have not been evaluated experimentally. However, there is a possible theoretical framework within the domain of information theory for the concept of numbers of different things. The information theory concepts of logon and metron may help to provide a mathematical structure for this problem. These information theory concepts are approximately defined, ignoring the concept of bit, as follows:

(1) The number of distinguishable groups or clusters in a representation, the number of definably independent respects in which a representation could vary, or dimensionality of number of degrees of freedom in a dimensionality all are termed structural information content of a representation.

(2) The unit of structural information, one logon, is that which enables one such new distinguishable group to be defined for a representation. Thus, structural information is not concerned with the number of elements in a pattern, but with the possibility of distinguishing between them. Logon content is a convenient term for the structural information content, or number of logons (number of independently variable features), in a representation.

(3) The number of indistinguishable logical elements in a given group or in the total pattern is termed the metrical information content of the group of pattern.

(4) The unit of metrical information, one metron, is defined as that which supplies one element for a pattern. Each element may be considered to represent one unit of evidence. Thus, the amount of metrical information in a pattern measures the weight of evidence to which it is equivalent. Metrical information that could be utilized represents the certainty with which the various characteristics of a logon define that logon (i.e., probability that $A = A$, and $A \neq B$). Thus, the amount of metrical information in a single logon, or its metron content, can be thought of as the number of elementary events that have been subsumed or condensed to form

it. For example, in the case of a numerical parameter, this is a measure of the precision with which it has been determined. These elements are indistinguishable; their number is not the number of binary digits to which the logon is equivalent.

Lacking a theoretical structure for the project undertaken in this report, the design consideration progressed by attempts to maximize the logon content of the space station in terms of instantaneously and temporally offered opportunities for change. The strategy, for example, of utilizing multicolored walls for the personal compartment is a first-level approach. Providing multicolored lighting, which in turn alters the patterns on the wall as well as dramatically influencing the hue and saturation of these patterns, is another level. Providing intricate levels of patterning the patterns on the wall is still another level of complexity.

Of course, major questions are still unanswered concerning the operation of relevancy of portions of a representation. For example, a representation with a lower logon content may provide greater functional environmental richness than a representation with a higher logon content if the variation in the forms of the former include more personally relevant interactive logons than the latter. This is pure speculation, however, because the qualitative and quantitative effects of stimulus variety that operate at the center of attention are not known; the differences between those stimuli and stimuli at the periphery of consciousness also are not known.

Audition

As pointed out previously, sound is one of the modulators for the human perception of space. Thus, noise is one of the most important elements to be kept under control. Dr. J. Beatson Hird (ref. 67) states that "Noise and lack of privacy are two of the most important factors which lead to tension and anxiety." Acoustical tolerance limits should be defined at the beginning of the spacecraft project and monitored throughout the program to ensure compliance with MSFC-STD-267A.

Olfaction

During previous completed space flights, body odors became excessive primarily because of the rather primitive hygiene facilities. Odors can be controlled by a combination of the environmental control system, hygiene area isolation, and good personal hygiene. All of these factors must be included in the space station design to provide acceptable odor control.

Some odors are culturally taboo, while others are acceptable up to the point where they become actually offensive. Adequate separation of odor generated from other crew members usually is accomplished by adjusting distance. Aboard a spacecraft, adjusting distance is not adequate because some odors are offensive at up to 10 ft (fig. 3-3).

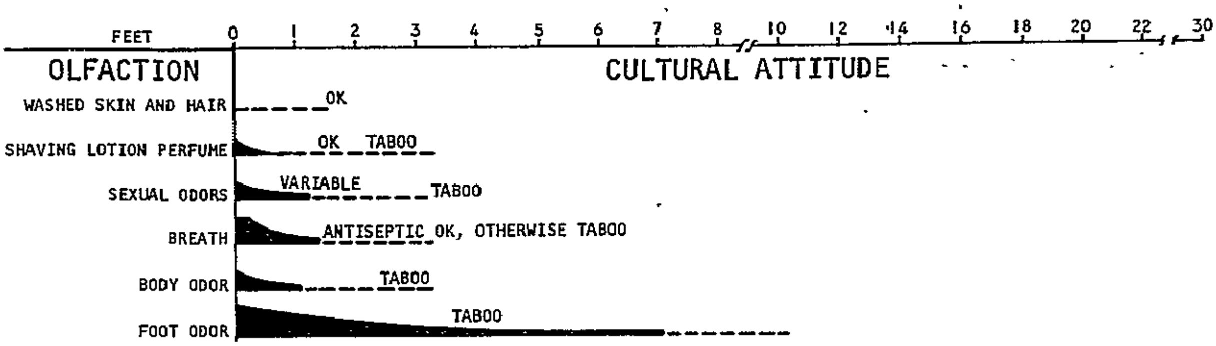

Figure 3-3. Cultural Attitudes Toward Odors (ref. 68)

Personal Space

Personal space has been defined by Edward T. Hall, Ph.D., documented in proxemics, and more recently documented by Stanley Deutsch, Ph.D., NASA, in his paper presented at the First National Symposium on Habitability. Several experimenters perceive personal space as a series of bubbles that have measurable dimensions and surround the individual (ref. 69). The four major categories listed are intimate space, personal space, social space, and public space (fig. 3-4).

All authorities in this area agree that overcrowing among humans in a stressful situation leads to harmful results. This is stated by Hall (ref. 70) as follows: "When stress increases, sensitivity to crowding rises--people get more on edge so that more and more space is required as less and less is available." Gerhard (ref. 71) states the same thought another way: "Some people have each his own space bubble where trespass is felt as injury and aggression. The language has many expressions which show this idea: getting one in, getting under one's skin, all express a dread of being crowded physically or emotionally."

Group interactions and tasks must be evaluated and the habitat designed to eliminate crowding. This is usually an iterative process, and in the final analysis, the adequacy of space can be evaluated only by an observer who is in it. A full-scale mockup with subjects acting as crewmen is used to accurately evaluate special uses. Three-dimensional space must be evaluated three-dimensionally.

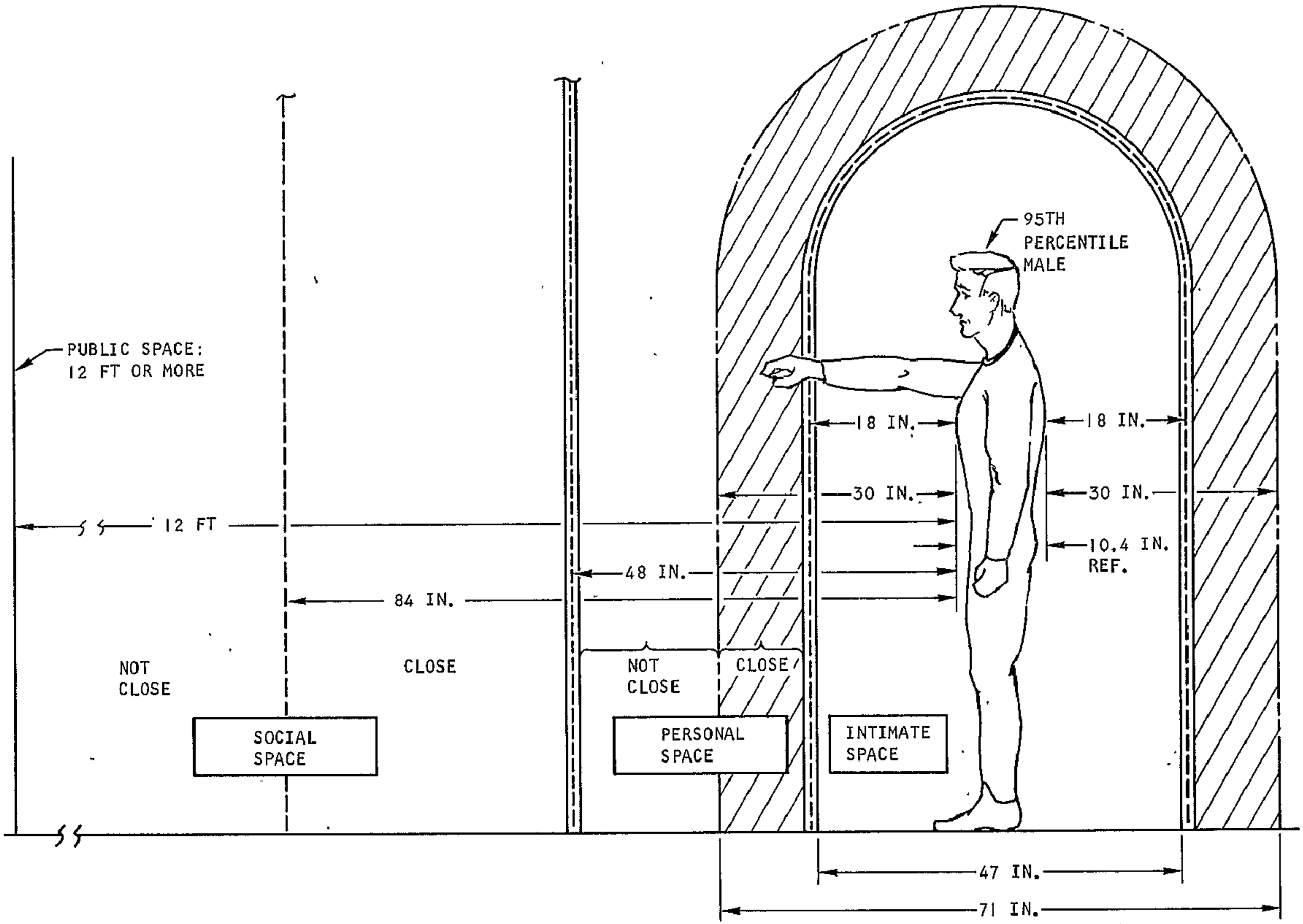

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Figure 3-4. Major Categories of Individual Space Surroundings

Personal Territory

Personal territory requirements are derived from two major needs: the need for privacy and the need to have a place to call one's own.

The need for privacy stems from the desire to eliminate external stimuli, both audio and visual, from all sources. The literature contains many quotes concerning the need for privacy and its importance. The quotes include:

> "Territoriality seems to be a function that varies with microcultural patterns. Man's boundary does not begin and end with his skin. If we can think of man as surrounded by a series of expanding and contracting fields which provide information of many kinds, we shall begin to see him in an entirely different light," from ref. 73.

> "The study of territorial boundaries and their legal impact is a labyrinthine topic, but a great deal is known about ways that species other than man work out their territories," from ref. 74.

Territoriality has two major aspects: the territories established by an individual; and territorial acts or responses. Territorial responses are actions taken by an individual to either obtain or to preserve territory. Territorial acts are by nature aggressive acts, and man does establish territories. Consequently, one design objective is to prevent the occurrence of territorial acts in a space station. The best way to accomplish this goal is to design for acceptable and functional demarcations of individual territory. This should be done in such a fashion that these individual needs are met and that a spacial etiquette and crew mores are established.

Mobility and Trafficability

The problem of mobility in space is especially concerned with man's ability to move about in the zero-g environment. Trafficability is the flow of the entire crew through the various compartments and levels of the spacecraft during the performance of a mission. Hatches, passageways, and aisles in community areas must be developed from trafficability studies. Only a few studies of zero-g trafficability have been conducted. Preliminary analysis of maneuvering requirements during free flight were developed during this study. (See Section 7). Much more needs to be done, however, especially verification of the data in actual zero-g conditions onboard a spacecraft.

Tactile

According to Hall, touch and visual spatial experiences are so interwoven that the two cannot be separated. The artist Braque (ref. 75) distinguished between visual and tactile space thus: "Tactile space separates the viewer from objects while visual space separates objects from each other." The

senses of touch and vision provide two channels of information that reinforce other sensory inputs. Vision is concerned primarily with orientation in space, while touch is more immediate and personal. Perceptual enrichment is primarily the result of these sensory interactions. Light, color, texture, and space are all elements to be manipulated by the designer to establish initial perceptual richness. Flexibility for the occupant to vary these elements must be included in the design for long-duration acceptance.

Positive Form and Negative Space

The arrangement of forms in space is performed by artists, sculptors, architects, and designers. Creating tensions between forms is a recognized aesthetic technique; however, even the most subtle arrangements are subject to viewer habituation. According to Robert Beck (ref. 76), "Different professions, age groups, and sexes approach and use spatial variables in significant varying ways, and hence have differing spatial styles as defined here." But the psychological meaning of space is yet to be determined, and spatial approaches to the perception of the environment require greater elaboration and further classification (ref. 76). It is clear from this and other data that fixed forms in interiors will please only those with similar aesthetic values and for limited periods of time. Flexibility to rearrange the furnishings within the space frame is one, if not the most, significant way to lessen habituation. Changing the space frame by removing or moving a wall also will provide a greatly changed habitat.

Vision

Most of man's information is gathered by his visual sense. Man also depends upon an integration of visual and kinesthetic messages to provide orientation in his visual world. A distinction must be made between the visual field (actual retinal image) and the visual world, which is what is perceived. All of the elements in the visual field must be integrated to provide perceptual richness and prevent disorientation in zero-g. The problem of integrating these elements is further compounded by the effects of habituation brought about by long-duration exposure. Since the old axiom, "beauty lies in the eye of the beholder," is still valid, it is not unreasonable for the crew to have a hand in selecting the interior visual appearance. Flexibility can be built into the design permitting change to interior, colors, lighting, texture, space, and arrangement of forms. The details of handling interiors are familiar to architects and designers who are experienced in designing for public use; however, they may create an environment that is totally alien to the tastes of the crew. Permitting the crew to participate in the decision-making process will get them ego-involved and create a positive acceptance of the craft.

ANALYTICAL APPROACH

To establish habitability guidelines and criteria for spacecraft on extended duration missions, a comprehensive approach was taken. A multidiscipline team consisting of architects, artists, designers, engineers, a physiologist, a psychologist, and a medical doctor contributed information and data pertinent to life in a defined space environment. This information was analyzed and the conclusions and results converted to criteria and standards for use by designers and systems and equipment personnel.

Analytical techniques were used to define typical mission requirements and constraints (fig. 3-5). Mission requirements are those things which the mission must be able to do, and mission constraints are the limits within which they must be accomplished. Requirements include (1) the mission or purpose of the system as a whole, and (2) the operational characteristics of performance requirements that detail the specific goals, objectives, and standards of the system mission. Constraints include the environmental, resource, cost, and time limits imposed on the system design by the state of the art, by nature, or by the procuring activity. In the absence of a precisely defined mission, a functions analysis was performed to establish typical functions that must be performed by the man/machine complex for living aboard a spacecraft. As shown in fig. 3-6, functions were reduced level by level until the next step indicated manipulation of hardware (i.e., turn on light), which then became a task. Task analyses were then performed to show crew actions and the hardware required. Timelines were constructed as required to show crew activities in time by areas of the spacecraft. Usage time of the areas is gathered from this chart, along with the movement from area to area, providing inputs to the trafficability investigation.

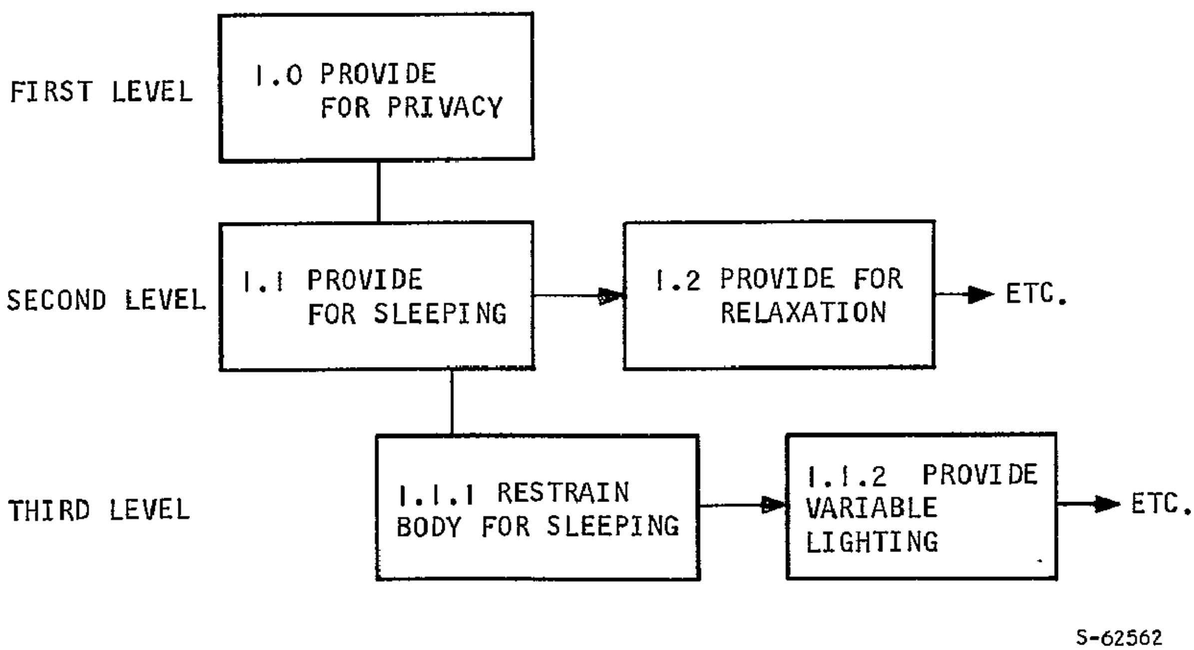

Figure 3-6. Levels and Numbering of Functions

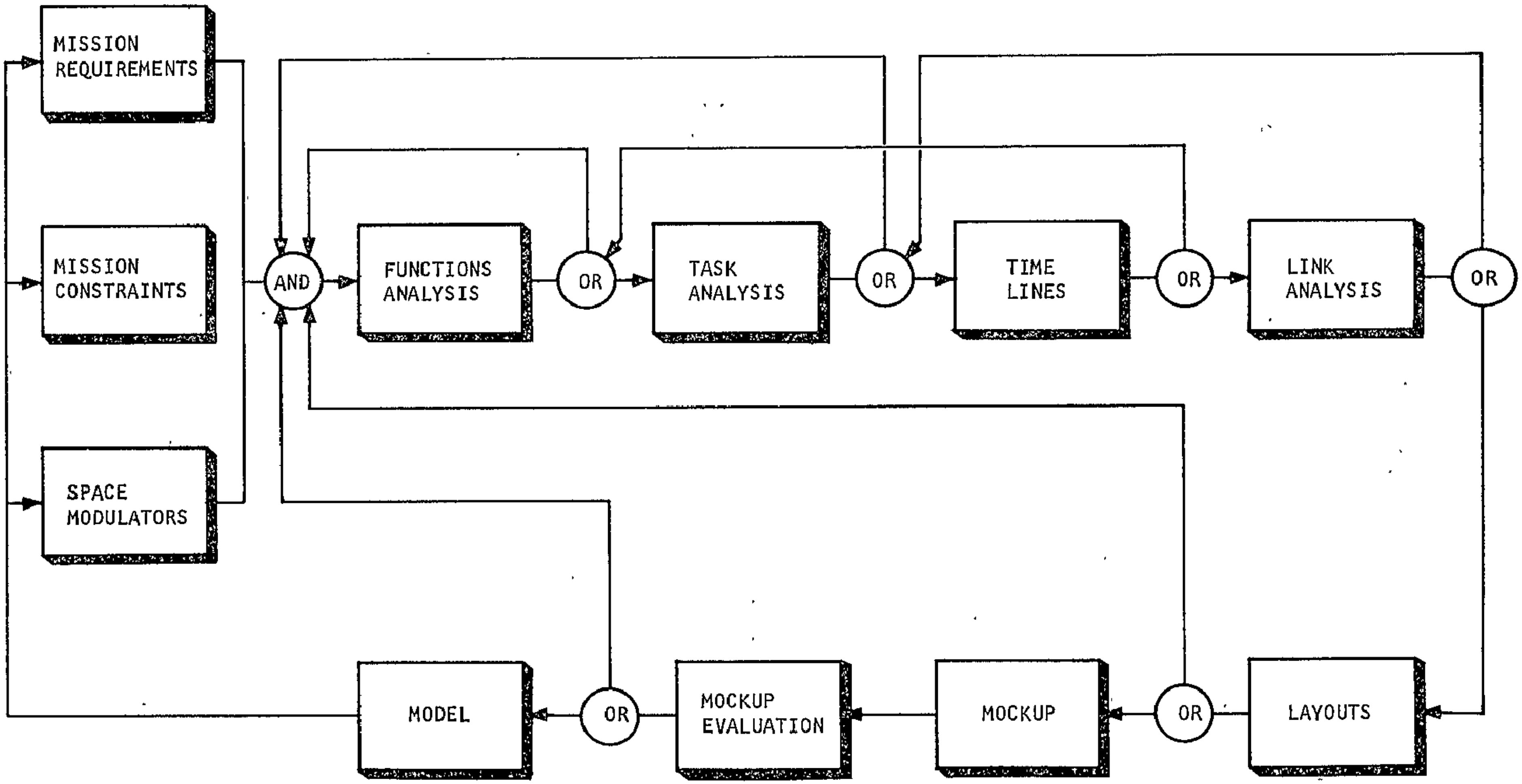

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Figure 3-5. Methodology Flow

FUNCTIONS ANALYSIS

A block diagram (fig. 3-7) was prepared showing those functions that must be accomplished by the crew and/or spacecraft to achieve mission success. A crew of 12 men was considered for a flight duration of one year. During crew rotation, two crews (24 men) must be maintained in the spacecraft for 2 weeks until the new crew is ready to take over.

Block 1.0: Provide for Privacy

Studies have shown that as mission duration increases, privacy becomes one of the most important contributors to crew well being. Therefore, some privacy must be provided for each crew member.

Block 2.0: Provide Sustenance

Food and water must be provided in sufficient quantity and quality to keep the crew physically fit; food and water also must be pleasing to the taste because good food that is well prepared will maintain crew performance and morale.

Block 3.0: Facilitate Recreation

Active and passive recreation must be provided to facilitate relief from normal duties. Recreation has primarily sociological and psychological impact on crew interaction by affecting morale, boredom, and physical and psychological tension.

Block 4.0: Maintain Physical Condition

All crew members must follow a prescribed exercise plan to maintain or improve their physical well being. The requirement to provide physiologic fitness for the crewmen imposes the need to:

(1) Maintain neuromuscular tone

(2) Maintain cardiovascular tone

(3) Minimize calcium mobilization from the skeletal system

Block 5.0: Provide Medical Care

The medical implications of long-duration exposure to the unusual gaseous environments of a spacecraft coupled with weightlessness are not completely understood. Many potential effects can be evaluated only in the spacecraft environment; therefore, contingency planning must be undertaken. Long-duration flight will require physiologic monitoring of the crew members to (1) detect

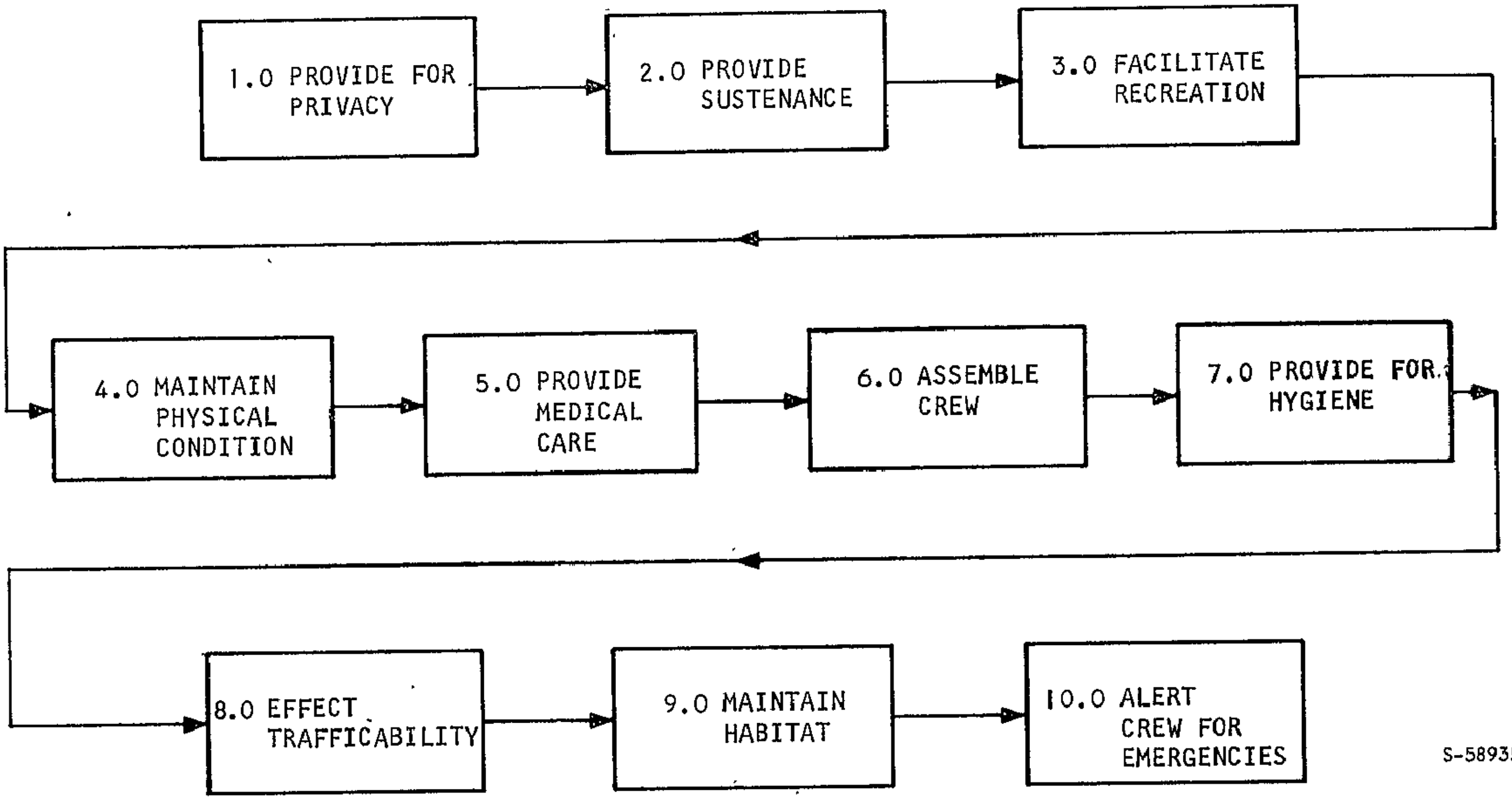

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Figure 3-7. First-Level Functions

subtle physiopathological effects and (2) evaluate fitness. Fitness would include acute illness and physiologic deconditioning in response to weightlessness.

Block 6.0: Assemble Crew

An assembly place must be provided for the entire crew so that information and instructions can be disseminated. During crew turn-over, both crews should be able to assemble for short periods of time to exchange information.

Block 7.0: Provide for Hygiene

The elimination of body wastes and maintaining body cleanliness are mandatory for long-duration space flights. Without these capabilities, increased filth and toxicity will result and threaten the life functions of the astronauts.

Block 8.0: Effect Trafficability

Traffic flow through the spacecraft must be easy, fairly rapid, and safe so that crew members can move from compartment to compartment and from station to station. Passageways and handholds must be provided for zero-g mobility.

Block 9.0: Maintain Habitat

The spacecraft interior must be designed to provide for quick and easy cleaning of accidental spillages of both wet and dry substances. Also, provisions must be made for removing lint, dust, and other substances that will slowly accrue during daily activities.

Block 10.0: Alert Crew for Emergencies

An alert system is provided in all compartments enabling the crew to be notified of emergencies. Due to the serious nature of some emergencies, both audio and visual techniques must be used. Pressure suits must be readily accessible and easy to don.

TIMELINE

The timeline chart of typical crew activities shown in fig. 3-8 depicts the approximate hours that would be spent in each location. Traffic from station to station also is estimated as the crew moves from activity to activity. In addition to scheduled and planned activities and traffic, random movements will be made during visits to the toilet, use of personal time, etc.

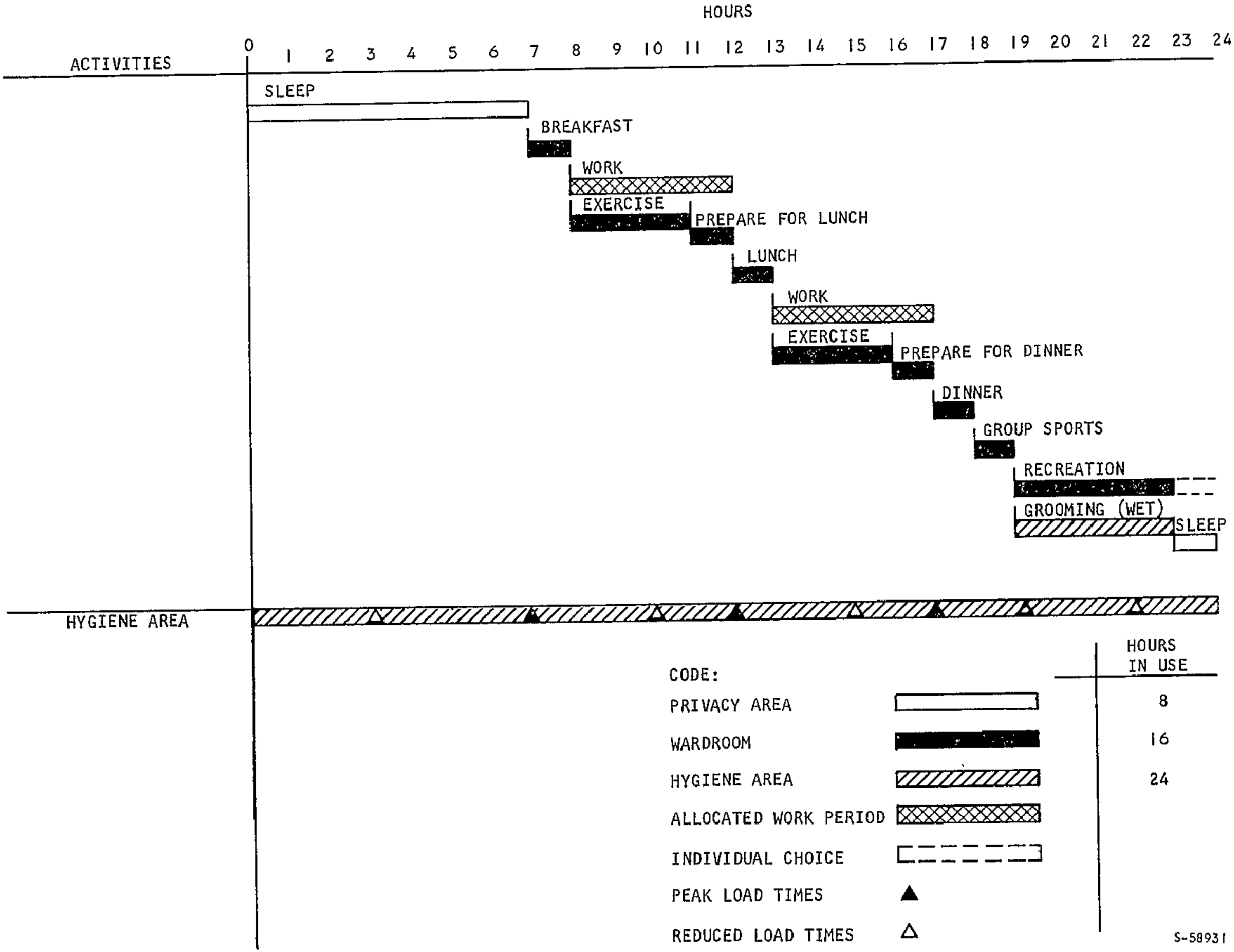


Figure 3-8. Timeline of Typical Crew Activities

VOLUME CONSIDERATIONS

Many studies have been conducted in the past to evaluate required areas and/or volumes necessary for multinumbered crews in confined and semiconfined quarters. Much has been learned regarding the detail constraints of such confinements over short periods of time, but very little has been quantified for extended duration missions. Although previous studies involved many unrelated situations, the commonality of the human subject in each case lends a measure of unification to the data reduction task. These early studies were concerned with occupied spaces such as prison confinement, submarine quarters, aircraft cockpits, and military barracks. Although all these studies had biased considerations that disqualify their overall use for determining the required volume necessary for habitation of a spacecraft having operations for either short- or long-duration missions, the personal stress may be correlated to some extent as shown in Table 3-I.

Spacecraft crew volume requirements for extended duration missions are the result of many physical and nonphysical elements. Of first-order importance in these volume considerations are fundamental or physical requirements, sociological interfaces, psychological considerations, and physiological demands. If the usable volume is inadequate, psychological problems will probably arise. These psychological problems will be increased due to the sociological, physiological, and physical problems. As mission duration increases, the probability and level of psychological stress will increase. The larger the usable spacecraft volume, the easier it will be to obtain a more habitable environment. However, the positive effects of volume increases are dependent on relevant design and function allocation.

Volume requirements per man are determined by (1) the minimum free volume necessary to support basal crew member requirements of personal space, exercise, performance schedule, and hygiene; and (2) the volume that is logistically necessary for each crew member. When apportioning or describing required volumes versus duration, additional factors must be considered such as periodic resupply of food, water, and other expendables; and personnel rations. To satisfy these considerations, a family of curves must be prepared that define all individual volumes necessary to storage of food, water, etc. versus duration; then these volumes must be summed to obtain an overall volume requirement. If neither crew rotation nor resupply is feasible, the problem is reduced to determination of a time-dependent volume. Because these volumes are established for zero-g conditions, the mobility constraint is of utmost importance. To provide stable mobility, crew members should be able to touch the floor and ceiling simultaneously. This constraint fixes the ceiling height at approximately 6 ft 6 in., thereby allowing clearance for a 95th-percentile crewman and appropriate control for a 5th-percentile crewman.

There is little data in the literature concerning the differences between male and female in space; however, female occupancy of space stations should require few additional features that are not already planned for male crew members. There may in fact be some volumetric advantages with female crews as observed during Tektite. The female crew was quite content with the volume of

TABLE 3-1

REPRESENTATIVE VOLUMES

System	Duration, days	Crew size	Volume per man, cu ft	System	Duration, days	Crew Size	Volume per man, cu ft
Mercury, MA-6	0.33	1	47	Republic converted altitude chamber	14	6	211
Mercury, MA-7, MA-8	0.5	1	47	Douglas orbiting vehicle simulator	30	4	250
Mercury, MA-9	1.5	1	47	GE two compartment simulator	30	4	215
Vostok I	0.5	1	90	Martin lunar mission simulator	3 and 7	3	133
Vostok II	1	1	90	NASA Ames conical capsule	7	2	61.5
Gemini III	0.21	2	40	NADA long-range simulator	5	5	140
Gemini IV	4	2	40	Submarine Nautilus, 1956	11	36	1600
Gemini V	8	2	40	Submarine Seawolf, 1957	60	100	570
Gemini VI	1	2	40	Submarine Nautilus, 1958	4	100	570
Gemini VII	14	2	40	Submarine Triton, 1960	83	100	570
Apollo	15	3	75	Armored vehicle M59	0.17	10	30
Early space station	21	3	285	Armored vehicle M113	0.33	12	23.3
Space plane	14	4	90	Armored vehicle M113	0.5	10	28
Inflatable space station	14	4	400	Armored vehicle M113	1	11	25.5
Space station	100	5	630	Armored vehicle M113	1	11	25.5
Space station	28	6	360	SAM: chair	4	1	25
Small space station	60	4	380	Confinement chamber, University of Maryland	152	1	1369
F-84 aircraft cockpit	2.5	1	30	University of Georgia fall-out shelter	3	0	65
WADD aircraft escape capsule 2	2	1	27.5	University of Georgia fall-out shelter	3	10	65
SAM simulator	7	1	47	University of Georgia fall-out shelter	3	10	52
SAM simulator	1.5	1	47	University of Georgia fall-out shelter	4	30	52
Vostok simulator	1	1	90	University of Georgia fall-out shelter	14	30	52
OPN 360 (Lockheed crew system mockup)	15	5	250	University of Georgia fall-out shelter	14	30	52
OPN 360 (Lockheed crew system mockup)	15	6	183	University of Georgia fall-out shelter	7	30	39
Hope II	15	6	187	USNRDL fall-out shelter	14	100	117
Hope III	30	10	110	USNRDL fall-out shelter	5	100	117
Hope IV	12	10	110	Lockheed Georgia flight station mockup	4	8	125
Hope V	12	10	110	Coffin-like open capsule	7	1	28
Hope VI	12	6	187	NAA space vehicle mockup	7	3	13
Hope VII	12	6	187	NAA space vehicle mockup	7	4	37
US Navy ACEL	7	6	75	NAA space vehicle mockup	4	2	200
US Navy ACEL	8	6	75	NASA University of Maryland	150	1	90
NAA conical mockup	7	3	67	AiResearch lunar exploration (LESA)	180	6	382
NAA cylindrical mockup	7	4	375				
NAA disk mockup	4	2	800				
SAM simulator	14,30, and 17	2	106				

the sleep area and spent much of their time in this location. Conversely, the male crew, due to their larger physical size, found this area to be uncomfortably small and confining, and spent most of their time in other areas. This area was used by the males only for sleeping. A great deal of study must be performed to establish scientific data on the human female in the space environment. One important study would be to investigate the female response to stressful situations.

Effects of menstruation on reaction were investigated by Pierson and Lockart (refs. 77 and 78). They found no effect on fatigue, work decrement, or endurance during simple repetitive tasks. A world track record was established by a female runner while in the middle of her menstrual period. A slight change or delay in the menstrual cycle caused by altitude or pressure change has been found, which also may be experienced in zero-g.

Additional volume will be required for not only storage but disposal of feminine hygiene supplies. Disposal in a separate receptacle is important to keep the design of the waste disposal system from becoming unduly complicated.

SECTION 4

ANTHROPOMETRIC, VOLUMETRIC, AND TRAFFIC STUDIES

4

ANTHROPOMETRIC, VOLUMETRIC, AND TRAFFIC STUDIES

ANTHROPOMETRIC STUDY

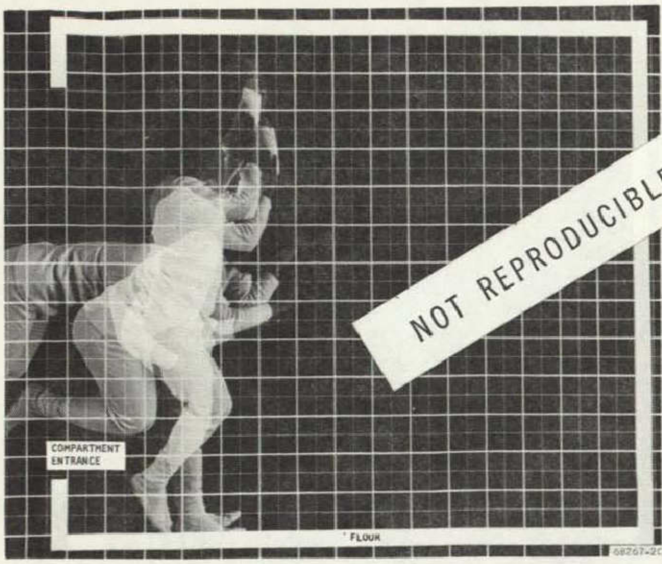
There is a general dearth of dynamic anthropometric data, and data concerning the space required for maneuvering in a weightless environment is virtually nonexistent. It was necessary, therefore, to determine maneuvering space requirements before the design objectives of this study could be pursued. To determine these requirements for use in spacecraft design, basic free-flight maneuvers necessary for mobility through a spacecraft were identified. Fifth and ninety-fifth percentile subjects were posed against a grid of 6-in. squares on a black background; the 6-in. squares were subdivided into 3-in. squares by white lines. White garments and a white headband were worn by the subjects to provide sufficient photographic contrast of the body and head. The positions selected for the subjects were those that best represented simple maneuvers within volumes pertinent to this study. The results of this simple study are shown in figs. 4-1 through 4-7. The activities of the man and his relative size (percentile) are noted in each figure.

VOLUMETRIC STUDY

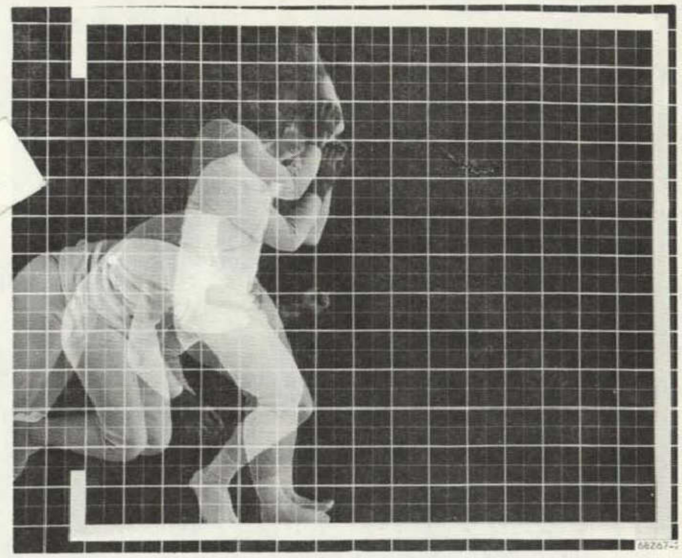
Volume dimensions can be determined by comparing the dominant view showing the action desired (side view) with the top or front view. Although some typical useful volumes have been generated (figs. 4-8 through 4-13), much additional information can be obtained by using the grid scales shown in figs. 4-1 through 4-7. Measurements can be made for many different body positions by reading the dimensions from different views.

TRAFFIC STUDY

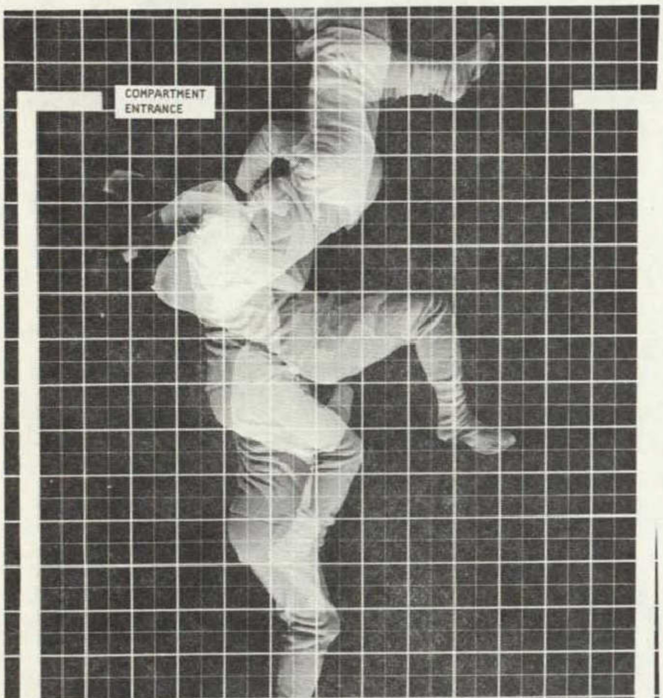
The problems of access through hatches and passageways have great impact on crew efficiency, safety, and performance, as well as on the configurations of the compartments being studied under this program. Safety considerations require that all hatches, compartments, and passageways must allow astronauts wearing space suits and portable life support system to move freely through the spacecraft. The use of pressure suits and life support packs, together with the desirability of having two men able to pass each other in a compartment entrance or passageway, must be incorporated in the final design. Passageways frequently considered are cylindrical in shape and are located in the center of the spacecraft. Cylindrical forms are perhaps the preferred structural configuration but are not necessarily the best for crew mobility.



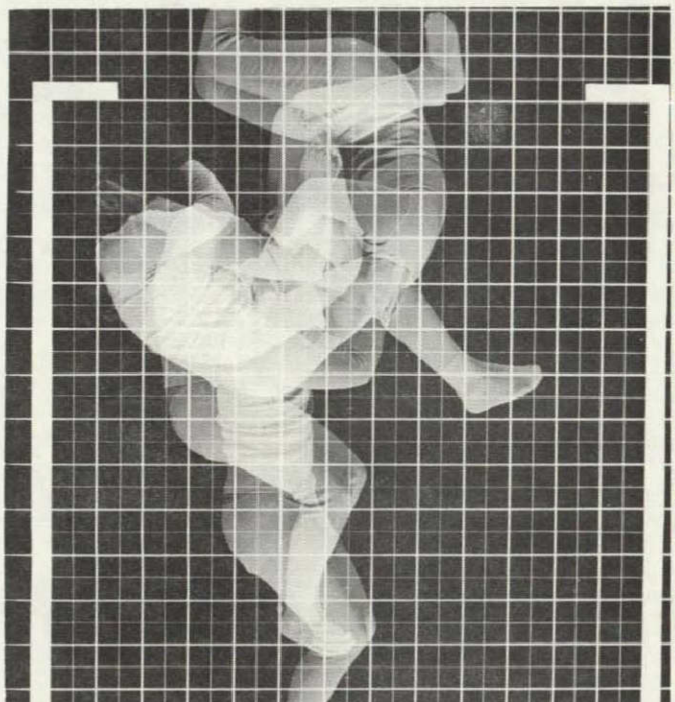
a. HORIZONTAL ENTRANCE (FIFTH PERCENTILE MAN)



b. HORIZONTAL ENTRANCE (NINETY-FIFTH PERCENTILE MAN)



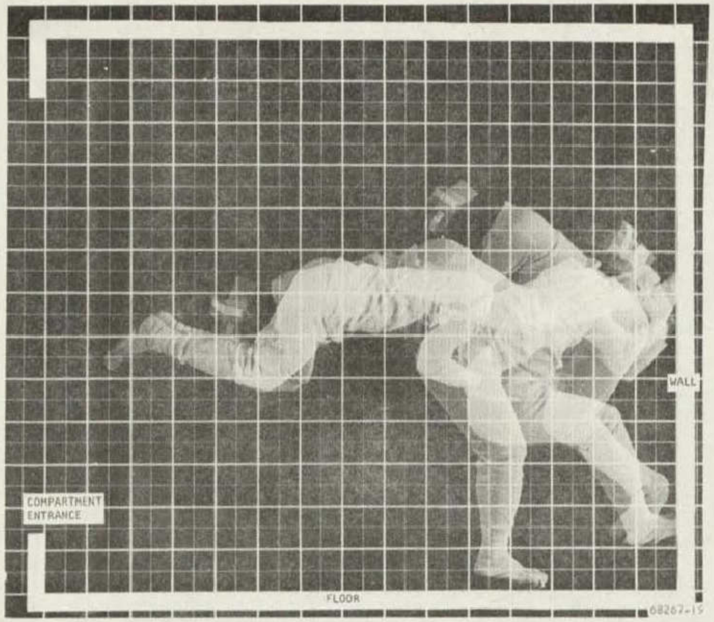
c. VERTICAL ENTRANCE (FIFTH PERCENTILE MAN)



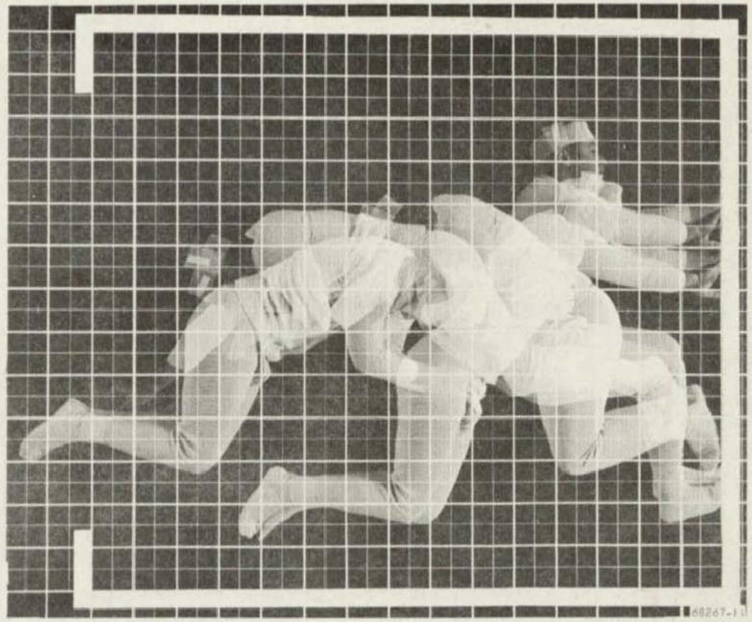
d. VERTICAL ENTRANCE (NINETY-FIFTH PERCENTILE MAN)

F-12682

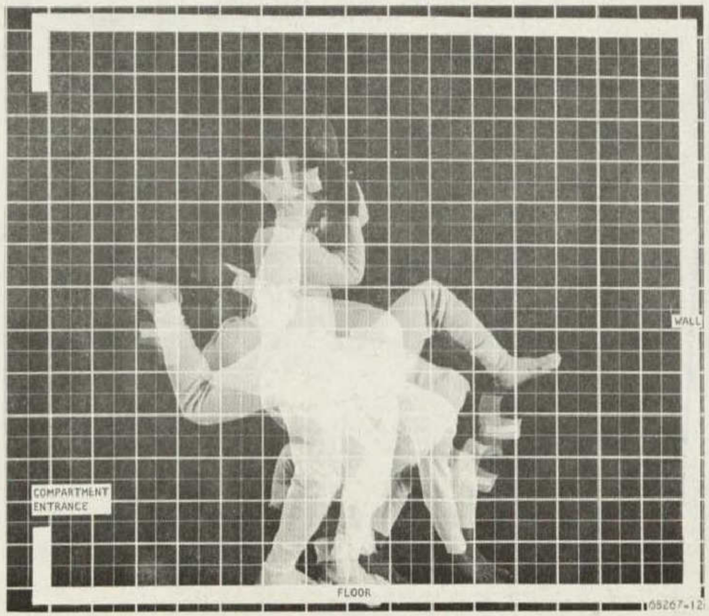
Figure 4-1. Fifth and Ninety-Fifth Percentile Men Entering Compartments and Orienting to the Floor



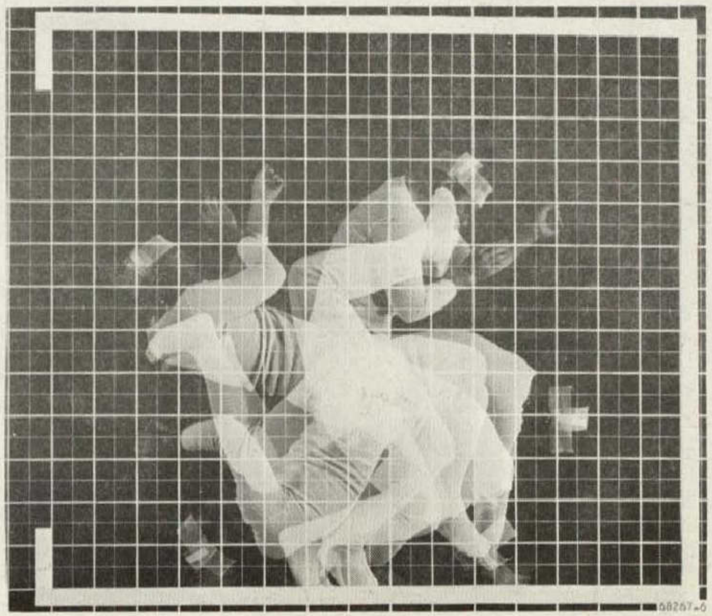
a. VERTICAL TURN FROM WALL (FIFTH PERCENTILE MAN)



b. VERTICAL TURN FROM WALL (NINETY-FIFTH PERCENTILE MAN)



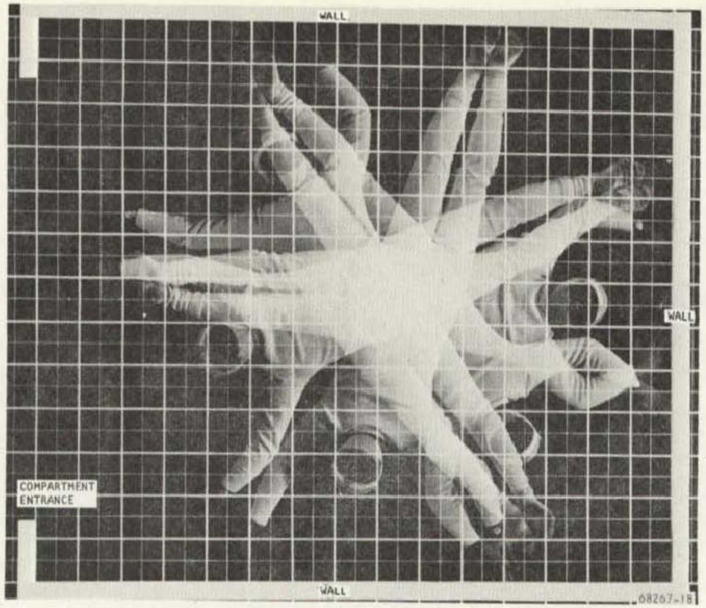
c. VERTICAL TURN FROM FLOOR (FIFTH PERCENTILE MAN)



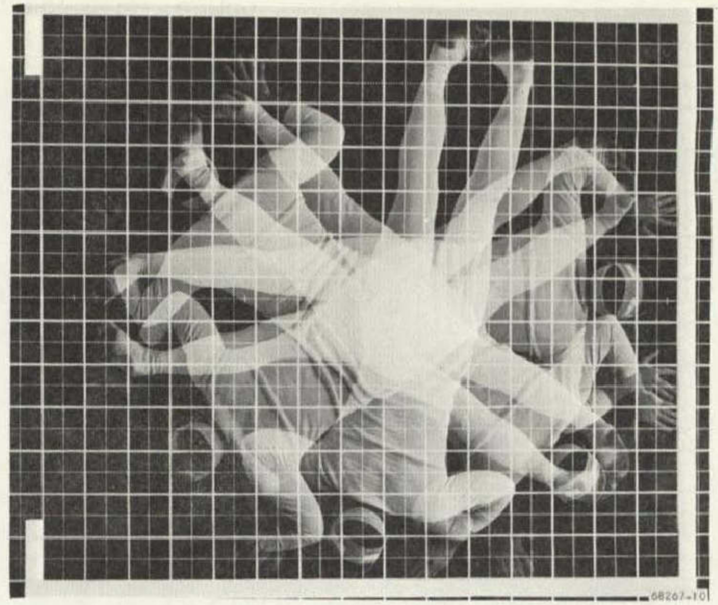
d. VERTICAL TURN FROM FLOOR (NINETY-FIFTH PERCENTILE MAN)

Figure 4-2. Fifth and Ninety-Fifth Percentile Men Performing Vertical Turns within Compartments

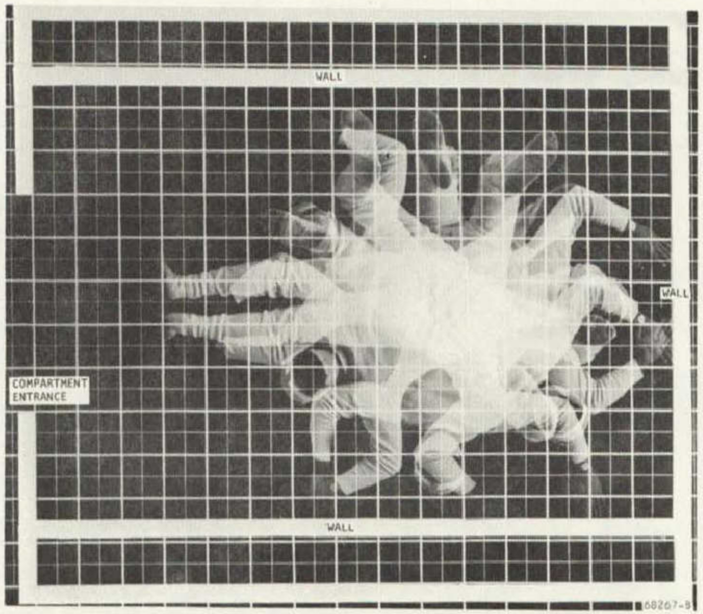
F-12683



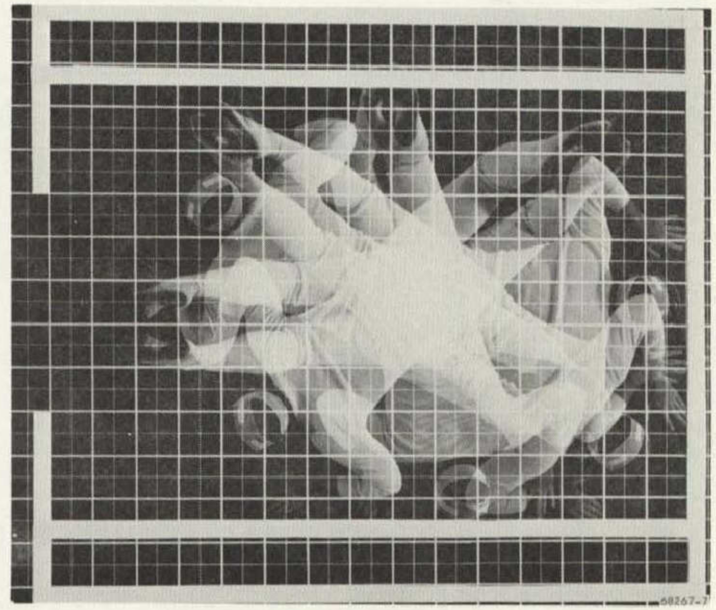
a. HORIZONTAL TURN (FIFTH PERCENTILE SUBJECT FACING FLOOR)



b. HORIZONTAL TURN (NINETY-FIFTH PERCENTILE SUBJECT FACING FLOOR)



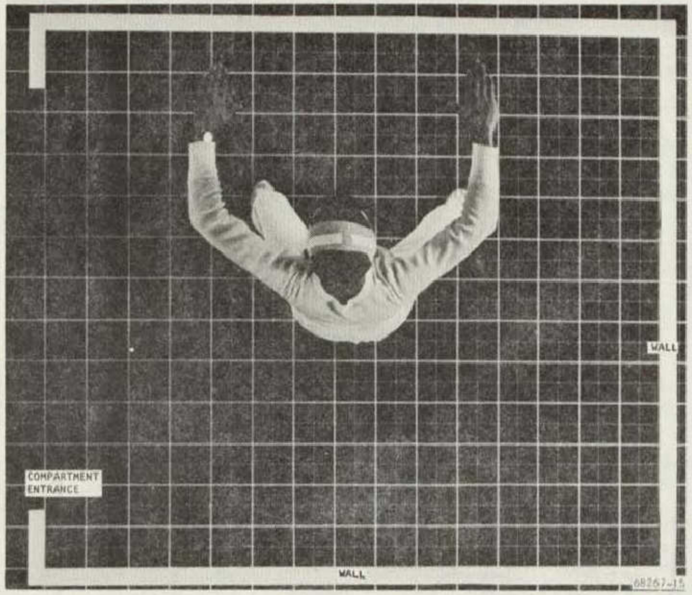
c. HORIZONTAL TURN IN CONFINED SPACE (FIFTH PERCENTILE SUBJECT)



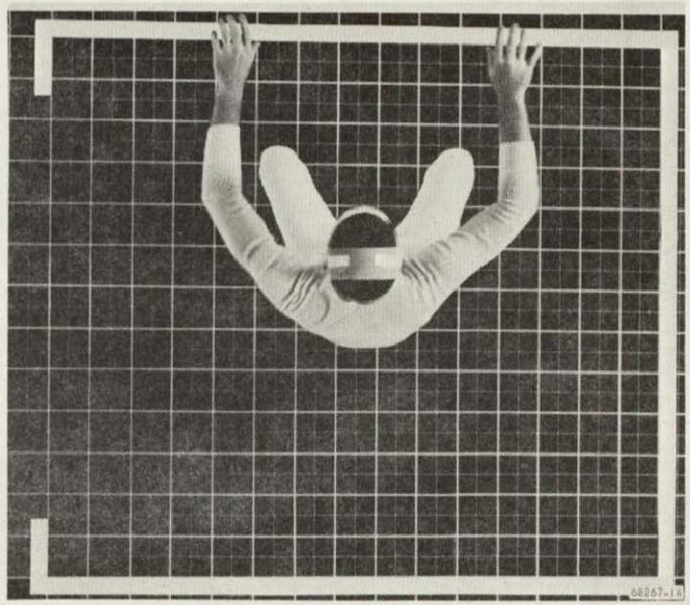
d. HORIZONTAL TURN IN CONFINED SPACE (NINETY-FIFTH PERCENTILE SUBJECT)

Figure 4-3. Fifth and Ninety-Fifth Percentile Men Performing Horizontal Turns within Compartments

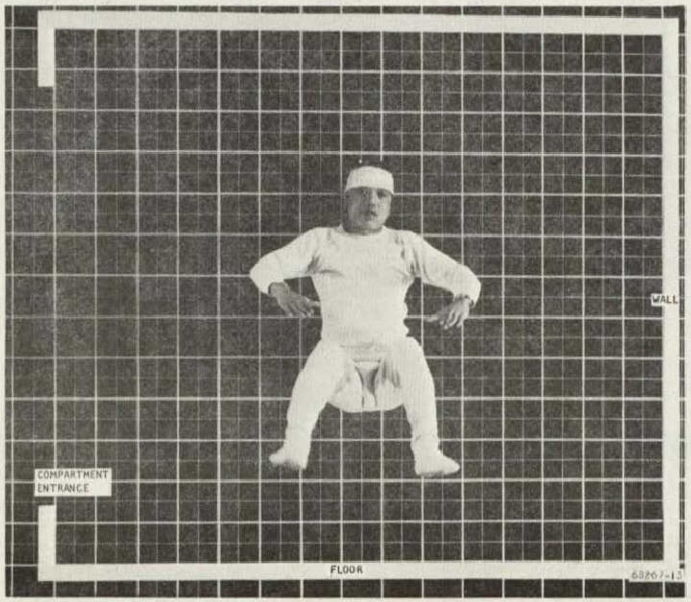
F-12688



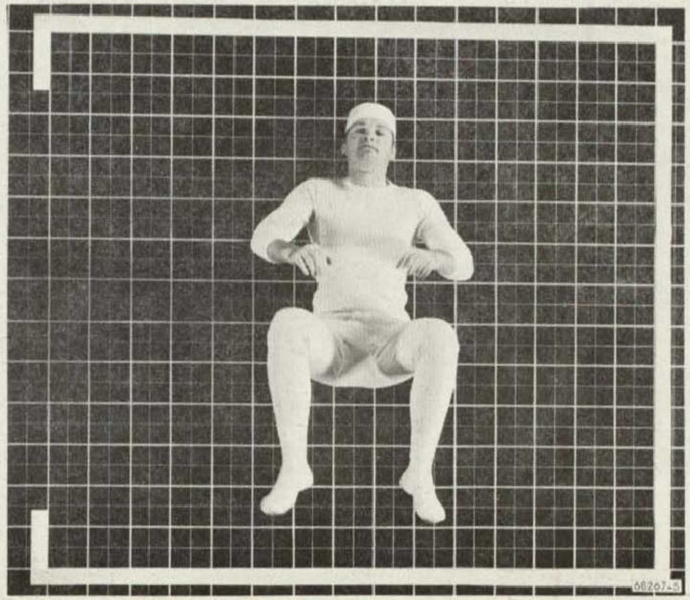
a. TOP VIEW (FIFTH PERCENTILE MAN)



b. TOP VIEW (NINETY-FIFTH PERCENTILE MAN)



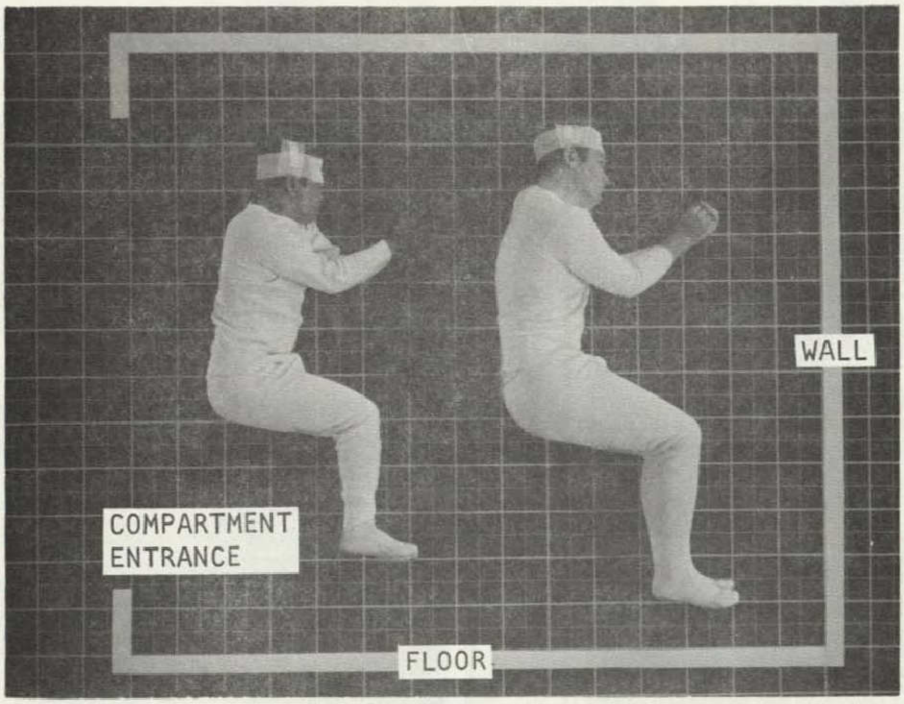
c. FRONT VIEW (FIFTH PERCENTILE MAN)



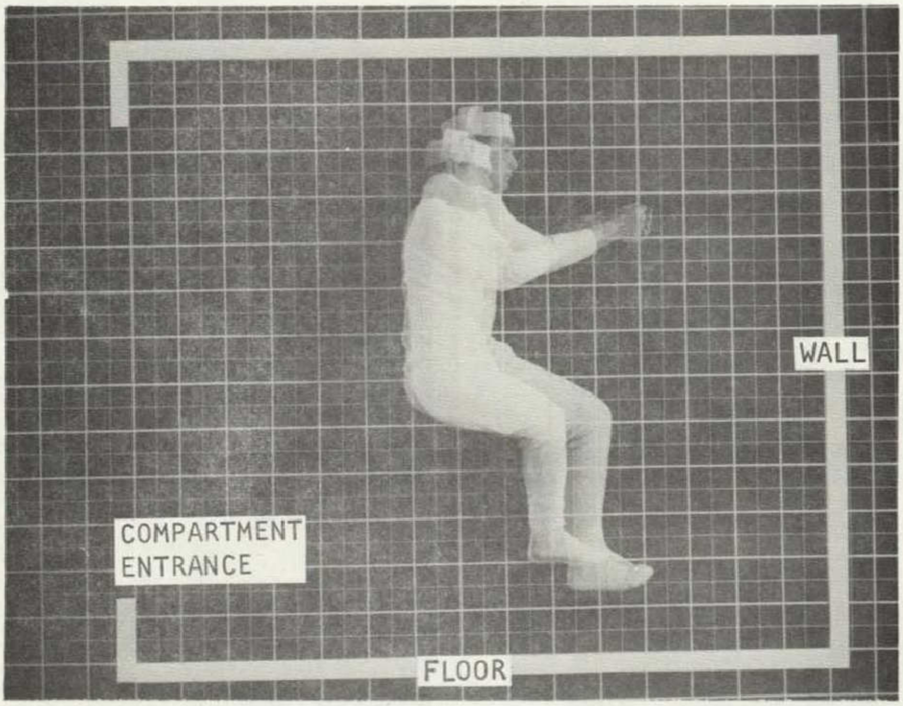
d. FRONT VIEW (NINETY-FIFTH PERCENTILE MAN)

Figure 4-4. Fifth and Ninety-Fifth Percentile Men Assuming Zero-G Positions

F-12685



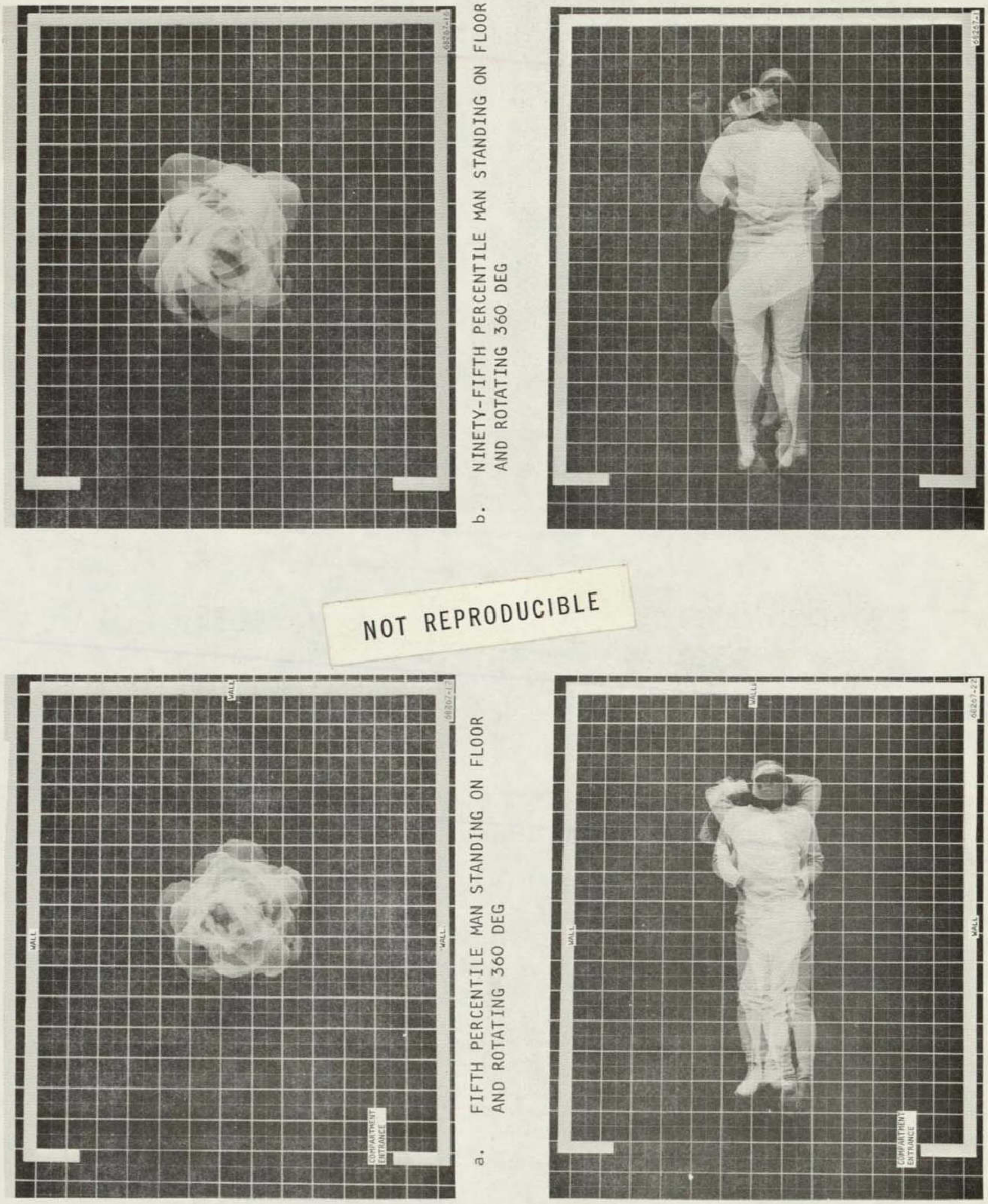
a. SIDE VIEW OF FIFTH PERCENTILE MAN SITTING BEHIND NINETY-FIFTH PERCENTILE MAN



b. SIDE VIEW OF FIFTH AND NINETY-FIFTH PERCENTILE MEN SITTING SIDE BY SIDE

F-12684

Figure 4-5. Fifth and Ninety-Fifth Percentile Men Assuming Zero-G Positions (Side Views)



a. FIFTH PERCENTILE MAN STANDING ON FLOOR AND ROTATING 360 DEG

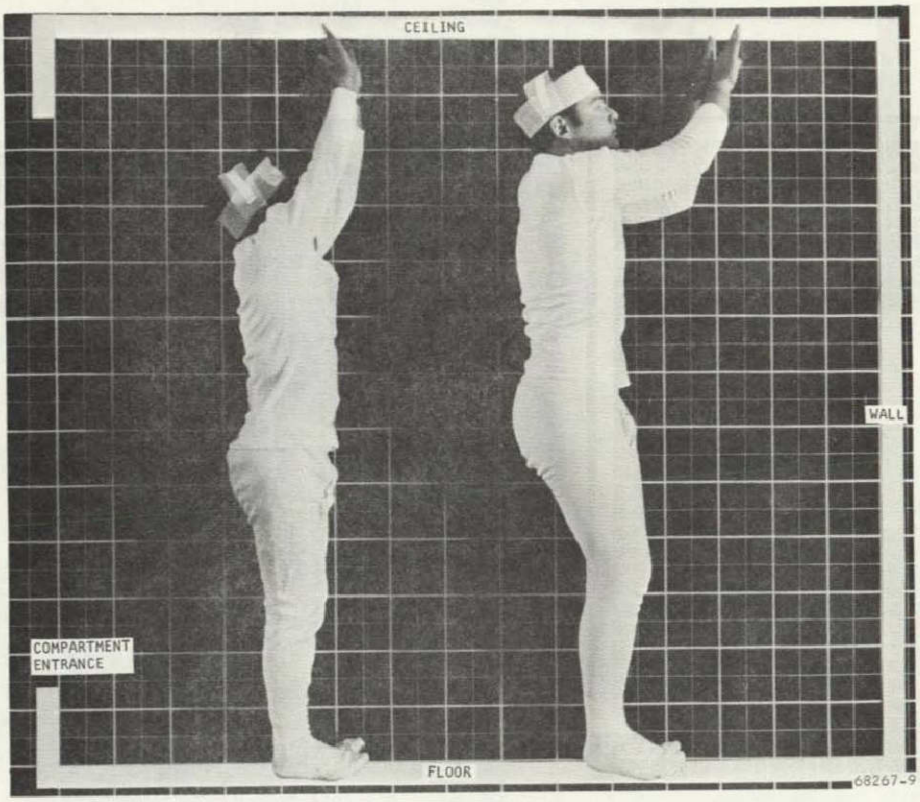
b. NINETY-FIFTH PERCENTILE MAN STANDING ON FLOOR AND ROTATING 360 DEG

c. FIFTH PERCENTILE MAN ROTATING 360 DEG IN PRONE POSITION

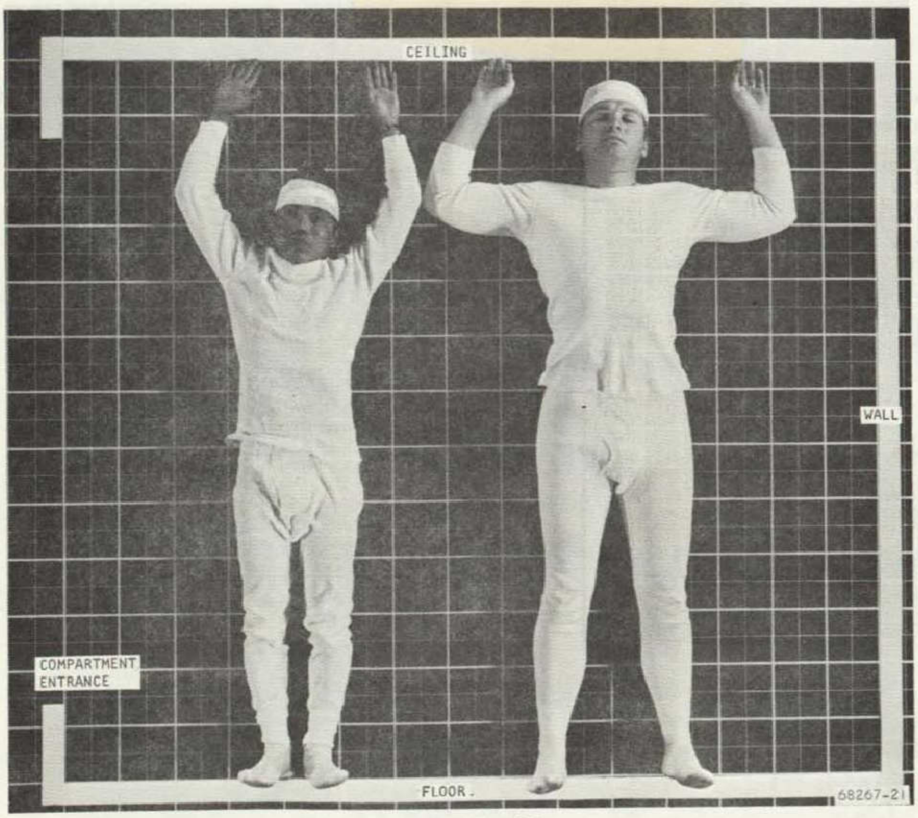
d. NINETY-FIFTH PERCENTILE MAN ROTATING 360 DEG IN PRONE POSITION

F-12687

Figure 4-6. Fifth and Ninety-Fifth Percentile Men Performing 360-deg Rotations



a. SIDE VIEW



b. FRONT VIEW

F-12686

Figure 4-7. Fifth and Ninety-Fifth Percentile Subjects Demonstrating Compression Standing

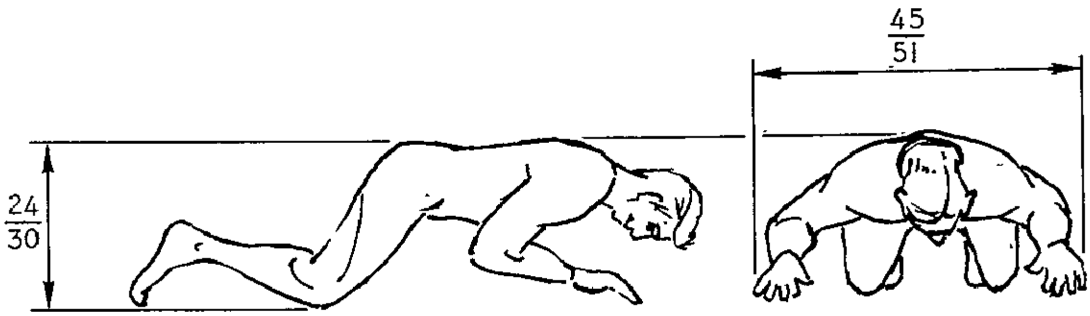


Figure 4-8. Translation through Compartment Opening

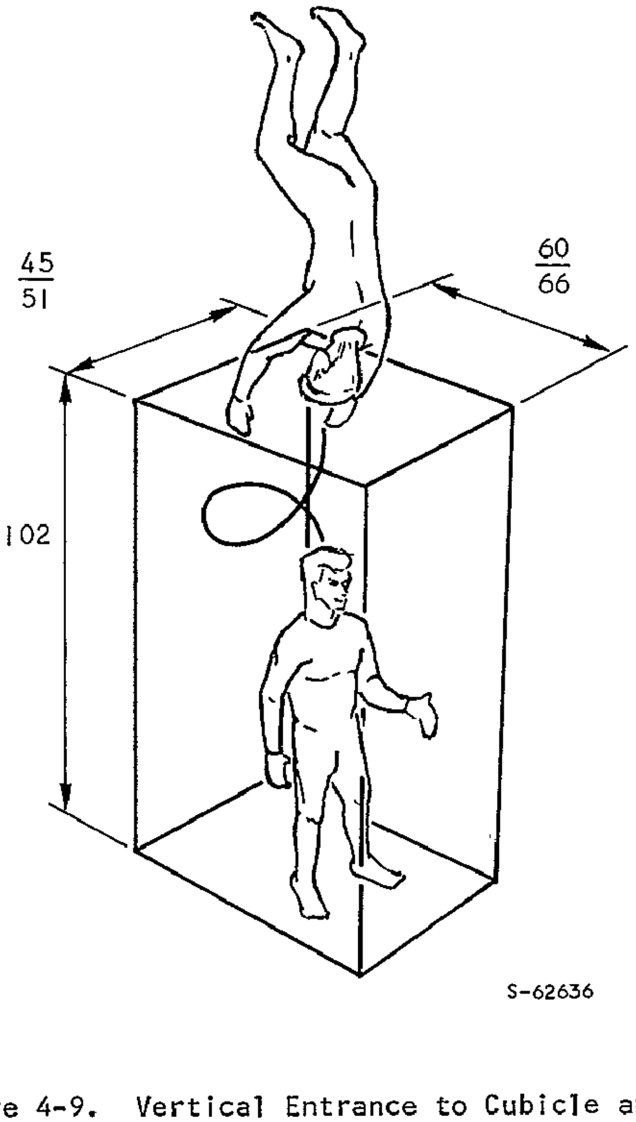


Figure 4-9. Vertical Entrance to Cubicle and Orienting to Floor

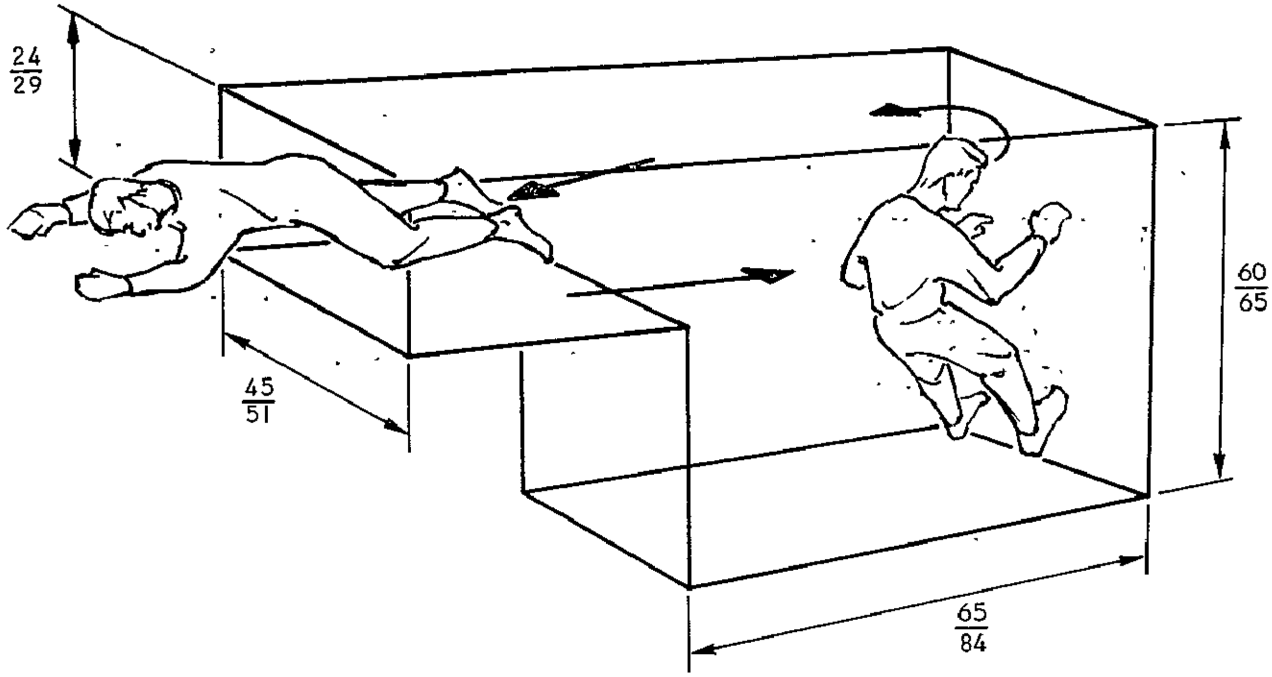


Figure 4-10. Turn off Wall

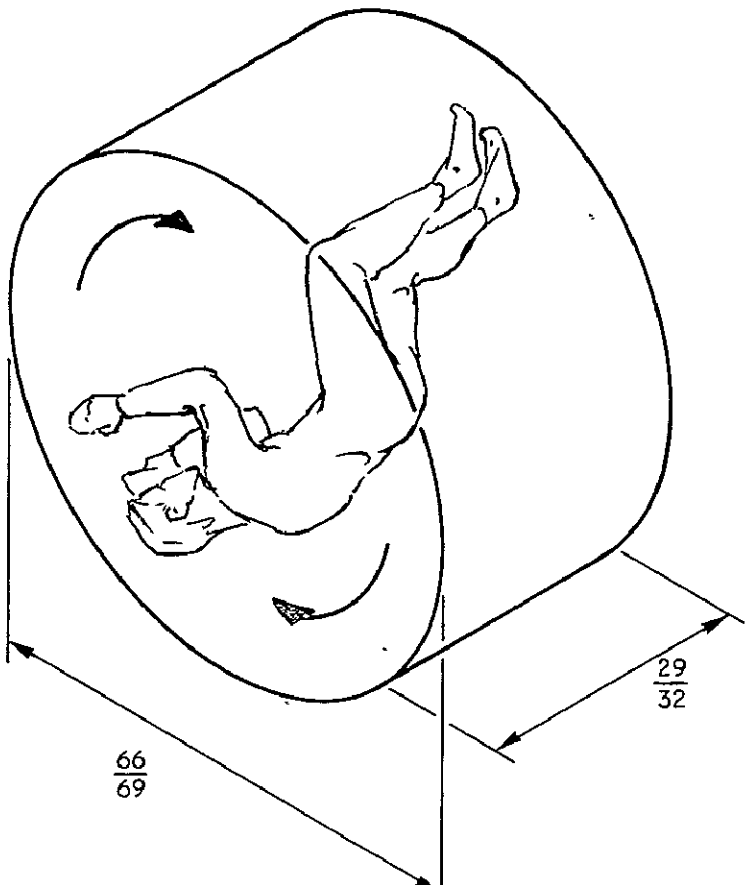


Figure 4-11. Vertical Turn

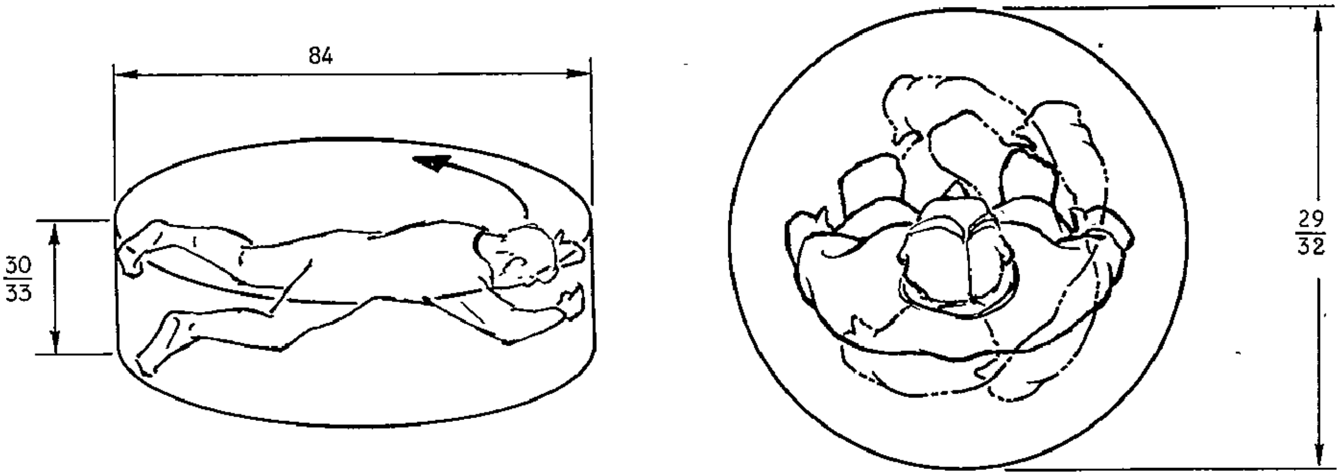


Figure 4-12. Horizontal and Vertical 360 Deg Rotation

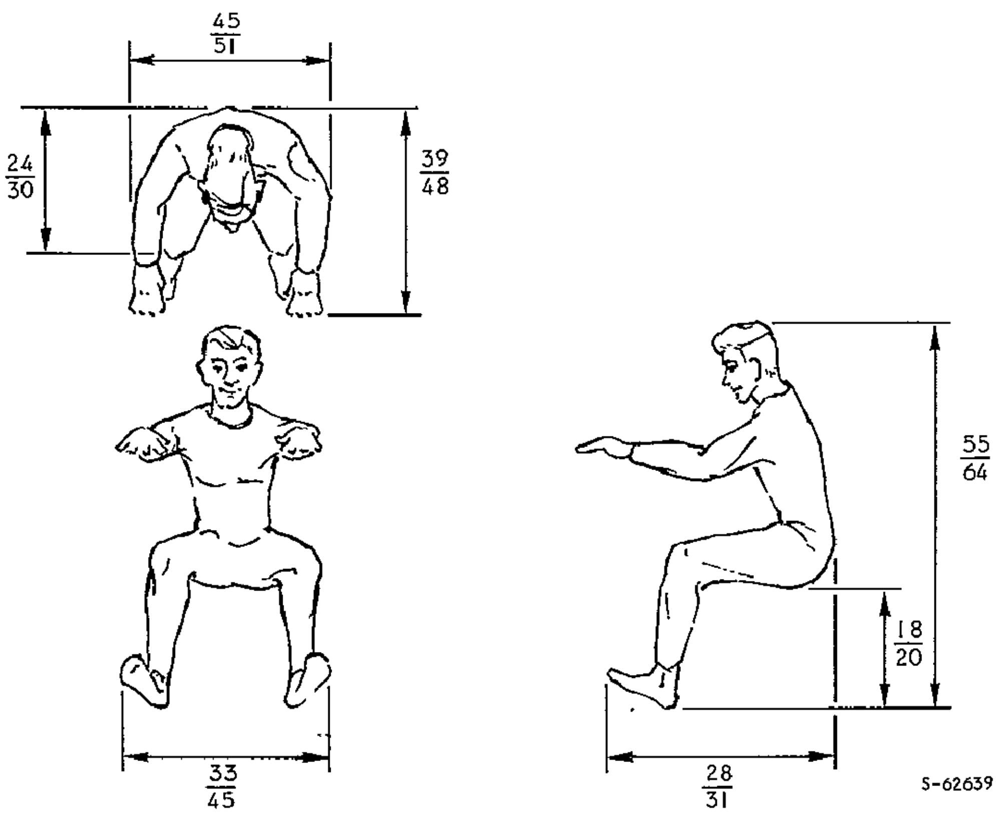


Figure 4-13. Zero-G Position

Various sizes of tunnels were considered that ranged from 42 to 58 in. in diameter, and were of both square and contoured cross sections. The 42-in.-dia tunnel does not allow two men wearing spacesuits and packs to pass each other. The considerations discussed above are illustrated in the following pages.

In fig. 4-14 a suited crewman wearing a backpack is shown traversing through a 30-in.-dia compartment entrance. A minimum 1-in. clearance between the astronaut and the hatch exists in the front, as well as only 1 in. between the backpack and the hatch. Due to this tight clearance, any angular displacement made by the astronaut while going through the hatch results in rubbing or snagging of the suit and pack. Although this distance does allow passage, it is not recommended. The pressurized spacesuit reduces the ability of the astronaut to "feel" his way through this restricted opening; this, coupled with the inability to see the hatch opening once his head has passed through, not only makes the task very difficult but very time-consuming. Compartment entrance criteria and standards resulting from anthropometric, volumetric, and traffic studies are presented in table 4-1.

In addition, the position of the suited astronatu shown in fig. 4-14 is very difficult to obtain when the suit is pressurized. The easiest way to pass through a hatch opening of this size is with both arms stretched above the head. Once the arms pass through the hatch, they can be used to pull the rest of the body through. However, this is a very difficult and combersome method. Use of the ideal traversing method (shown in fig. 4-14) becomes more practical as the hatch size is increased. In fig. 4-15 a minimum hatch opening size is shown for two men passing while suited and wearing packs. Approximately 1-in. clearance is shown between the nearest contact points, which results in difficulties similar to those discussed above, i.e., minor angular displacement will result in contact, etc. Appropriate design should increase these dimensions, especially in areas with high traffic density and where the entire crew is assembled at one time (wardroom and hygiene area).

In fig. 4-16 the minimum tunnel dimensions that allow two men to pass are shown. The smaller tunnel (42-in.-dia) is adequate for shirtsleeve (unsuited) operations but would permit only one suited member to pass through at a time. The larger tunnel (58-in.-dia) is the minimum diameter that will allow two suited astronauts to pass. A 60-in. diameter would be a more efficient size for this type of a tunnel carrying heavy traffic. Tunnels smaller than this could be used only for one-way escape. All tunnel surfaces should contain built-in traction devices or recessed hand holds (fig. 4-17), and care should be taken to design these tunnels such that zero-g trafficability is maximized. No hard or sharp surface should exist that could snag fingers or clothing during zero-g astronaut maneuvers. Conical or pleated recessed finger holds appear to be ideal for easy, rapid transit through the tunnels.

In fig. 4-18 an alternate configuration to the cylindrical tunnel is shown. This is a 75-in. square tube that will permit both fifth and ninety-fifth percentile males to walk on any surface or freely float through it. Zero-g floating can be halted at any time by reaching out and touching opposing surfaces.

TABLE 4-1

COMPARTMENT ENTRANCE CRITERIA AND STANDARDS

1. The compartment entrance must be large enough for suited crew members to negotiate easily during emergencies.	1. The 30-in.-dia compartment entrance is the minimum size for one man; this is based on anthropometry of flying personnel, with 95th percentile used as the worst case. Larger compartment entrances are recommended. (See fig. 4-14.)
2. Large crews (10 and up) will require the passing of crew members in main compartment entrances. These crew members will also be suited during emergencies (life-boat concept).	2. The 30-in.-wide by 58-in.-high compartment entrance is minimum for two suited crew members to pass during emergencies. Data from anthropometry of flying personnel with 95th percentile are used as subject size. (See fig. 4-15. The dimensions shown are based on known suit and backpack sizes.)
3. Hand grips are necessary for negotiating and operating hatches.	3. MSFC-STD-267A

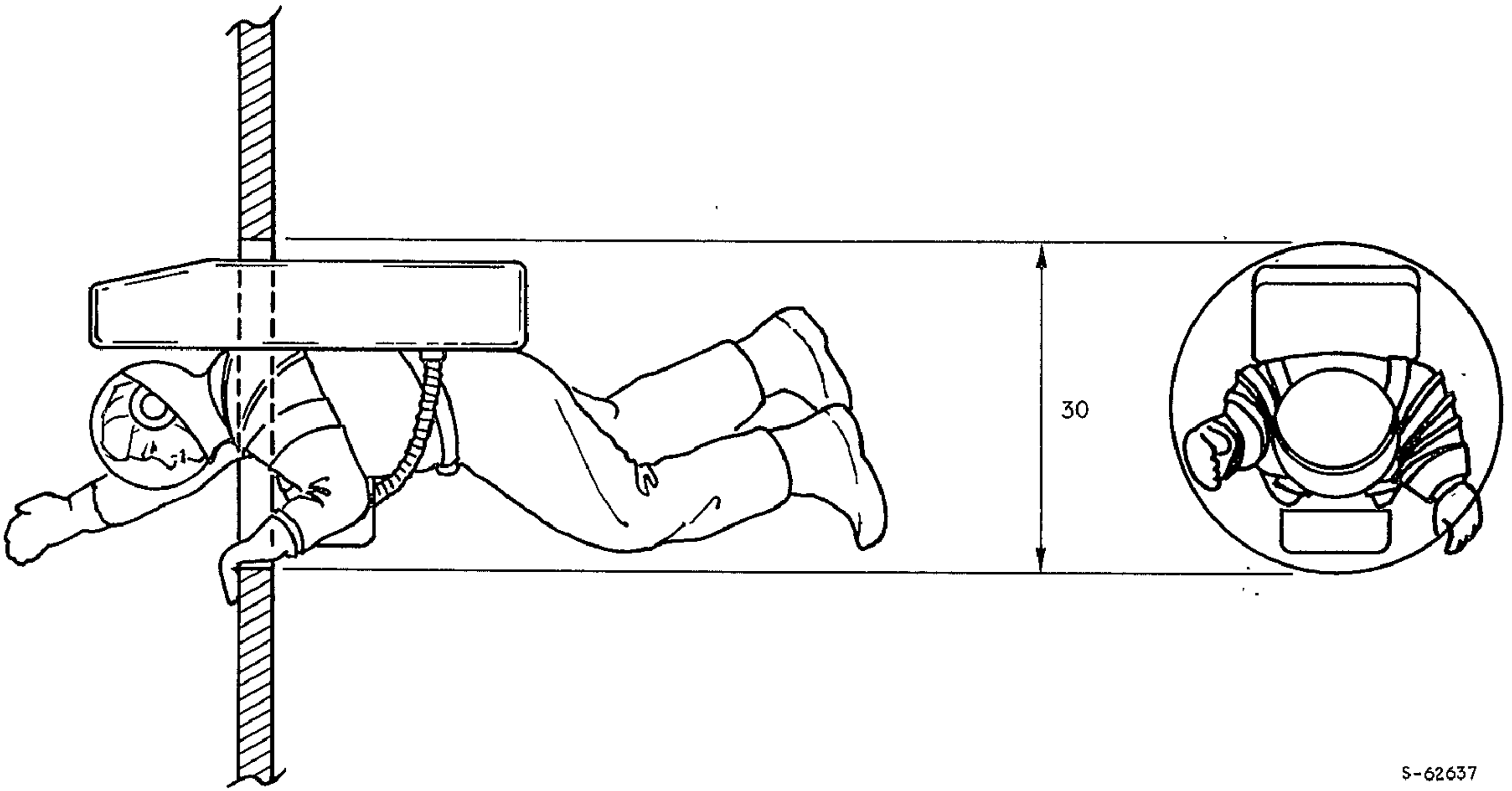
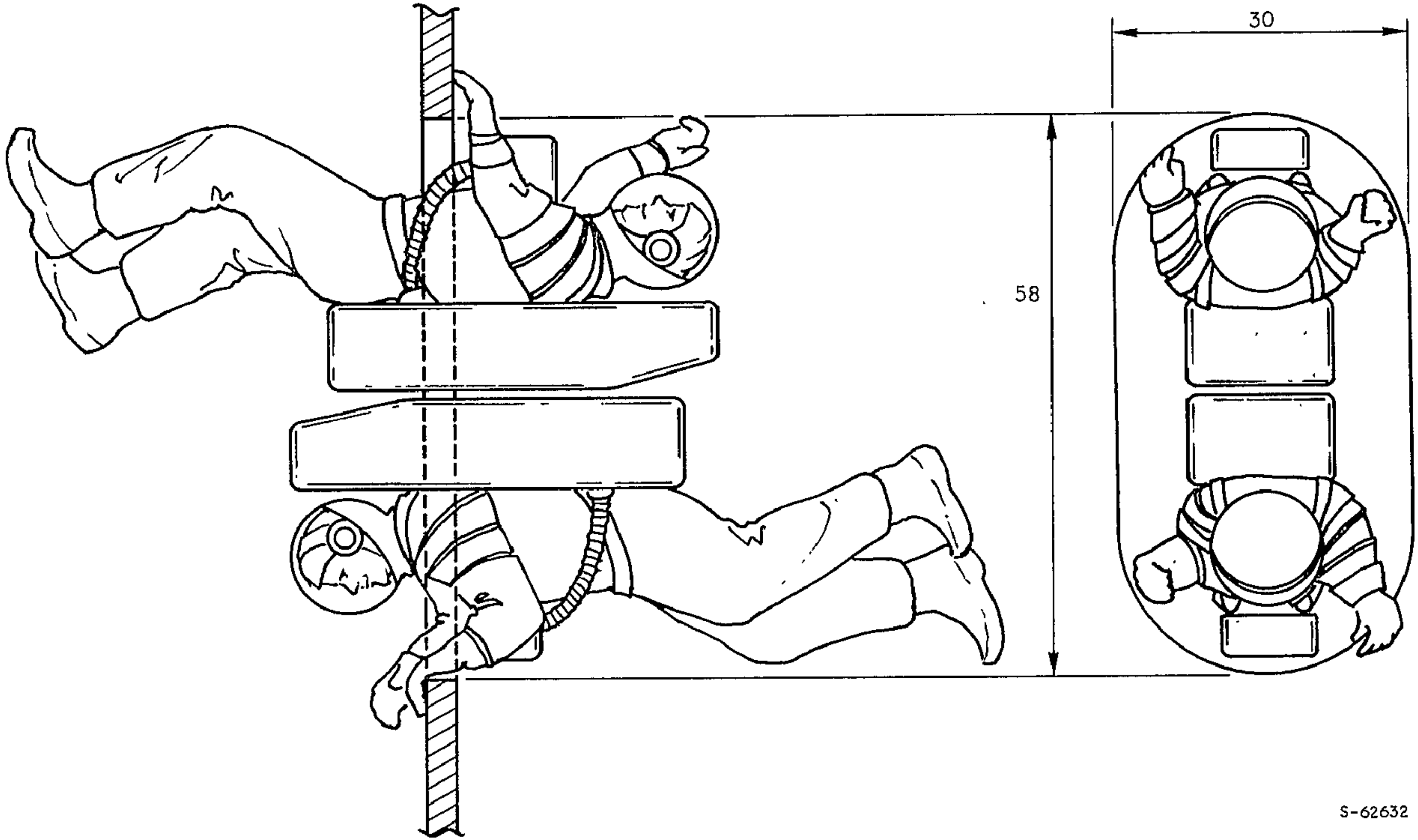


Figure 4-14. Ninety-Fifth Percentile Male, Passing Through Compartment Entrance Suited and Pressurized



S-62632

Figure 4-15. Ninety-Fifth Percentile Men, Suited and Pressurized

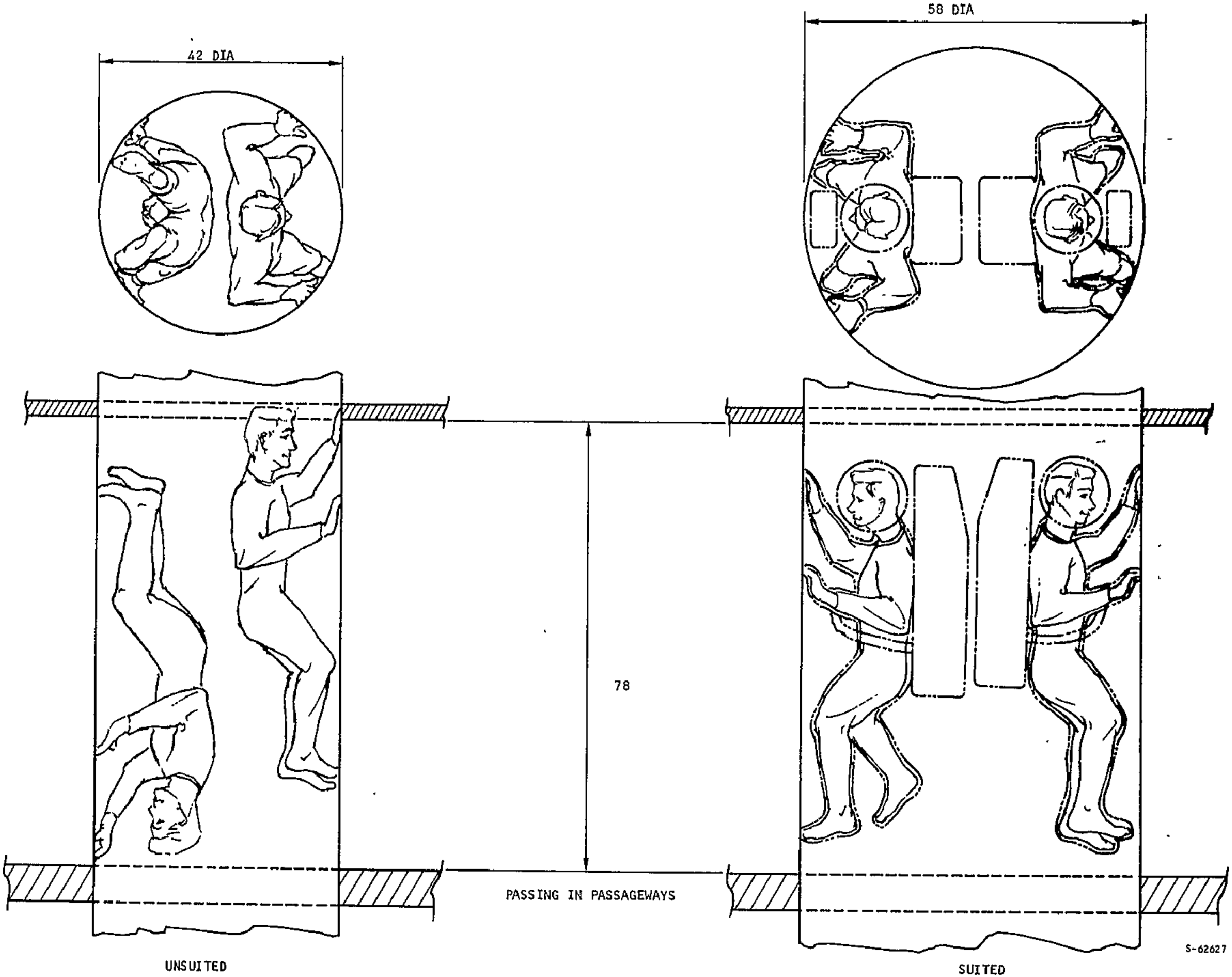


Figure 4-16. 95th Percentile Men Passing in Tunnels

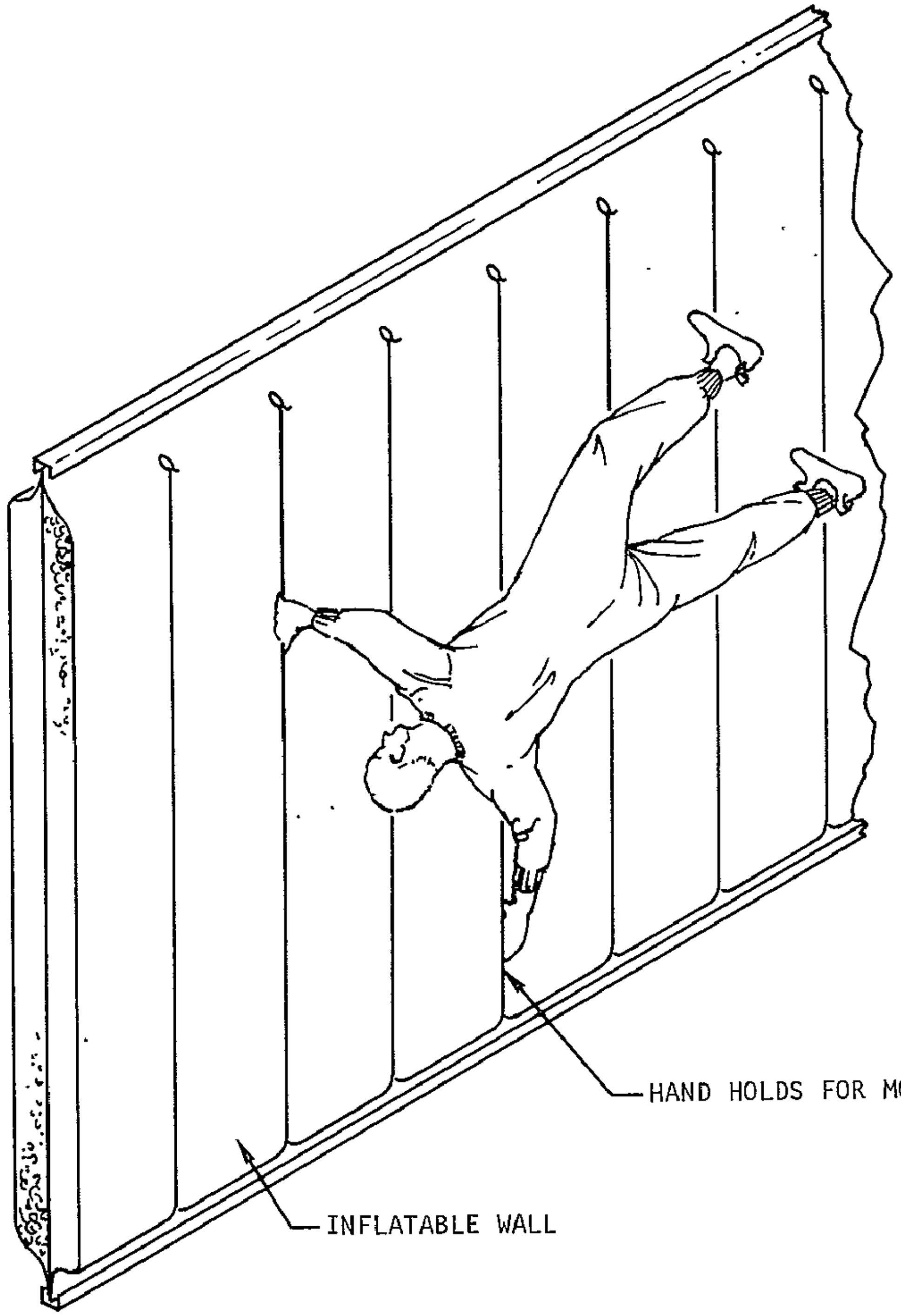


Figure 4-17. Traversing Along Wall

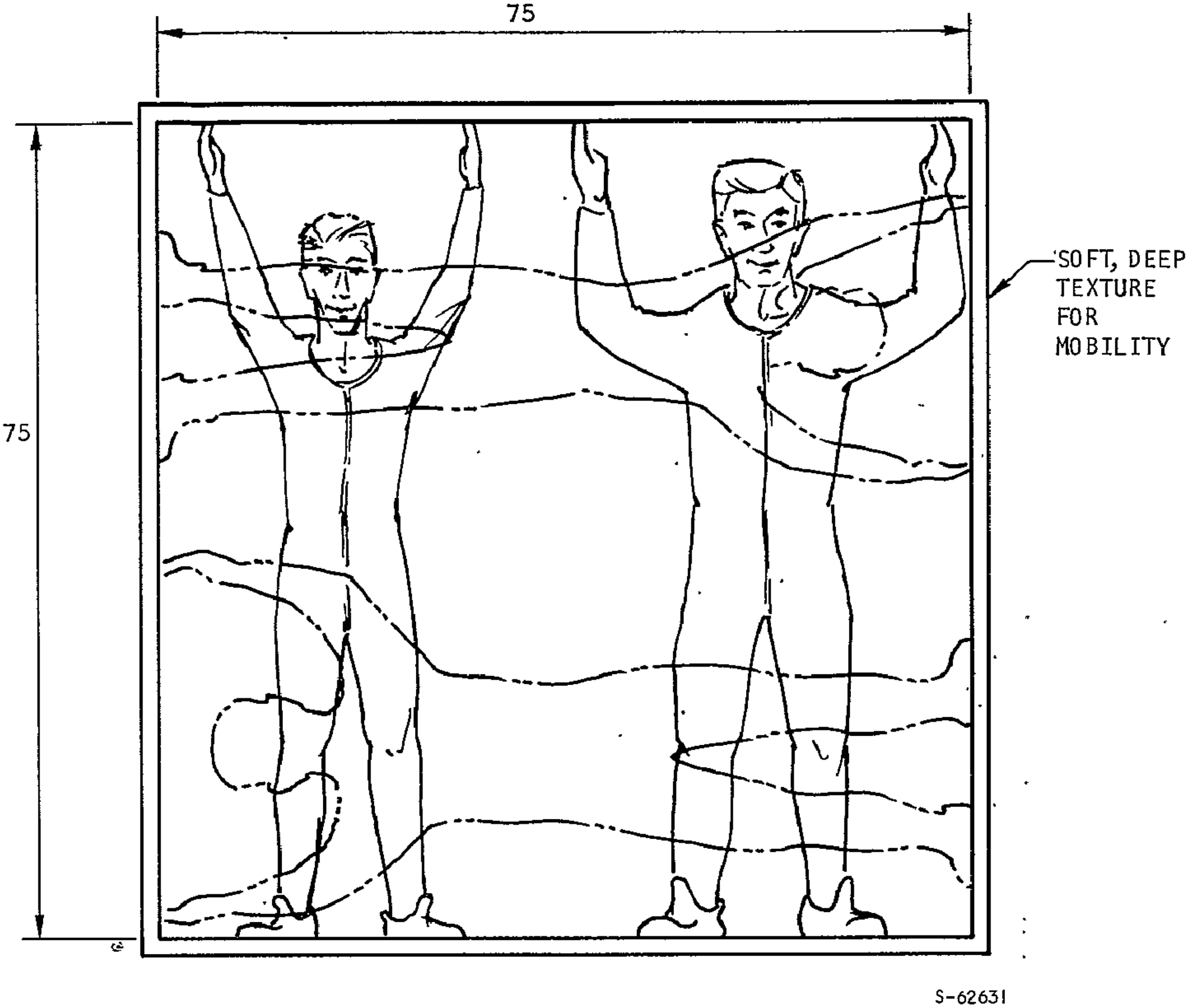


Figure 4-18. Square Passageway Concept

A configuration that offers good reach surfaces for all sizes of crewmen in various attitudes of mobility is shown in fig. 4-19. A contoured tunnel may also provide a more rigid structure than the square tube version.

Travel distances and body maneuvers necessary to perform zero-g maneuvers through the spacecraft were approximated for typical activities during a day in a four-floor cylindrical space station. Excursions from floor to floor are generalized for Plans I and II, shown in figs. 4-20 and 4-21, which illustrate the problems of traveling from compartment to compartment. A comparison of the plans shows the shortest distance traveled can be achieved by placing those areas with the greatest interaction next to each other. Since the wardroom and the hygiene compartments have the highest number of contacts (96 each) for a typical day, they are placed next to each other. Excursions were counted from the crew leaving the sleep area, translating to the hygiene area, then to the wardroom for breakfast, and then to the work area. From the work area, contacts made with the hygiene area during the day are in accordance with individual differences. For this study, an average of one trip to the hygiene area in the morning and one in the afternoon was planned. After the evening meal, trips are made from the wardroom to the living area and the hygiene area. Several random contacts may be made in the performance of tasks, but the configuration selected is adequate to identify the traffic flow and provide information for locating functions in compartments.

A comparison of floor arrangements within the spacecraft resulting from the stacking of modules is shown in fig. 4-22. Floors placed back-to-back (i.e., floor-to-floor), as shown in arrangement C, require only two complete turns to travel from floor to floor when completing each portion of the journey with the feet on the floor. Crewmen will probably pass head-first through the hatch in free flight. If this is not the case, arrangement A would not require any turns. Also, arrangement A is advantageous because locomotion to all floors is in the same direction. This should shorten the learning time and eliminate disorientation because all items aboard the spacecraft are related to a common place.

Flow diagrams based on the different floor arrangements (figs. 4-22 through 4-25) were prepared to show the major traffic patterns through the spacecraft. The diagram shown in fig. 4-23 is based on the preferred arrangement B (fig. 4-21) and shows that, in a cylindrical form, traffic can be simplified by arranging components in a radial manner to prevent cross-over or collision points. Paths shown in the work area are representative only, and have not been substantiated. The paths shown to typical work areas are more realistic. By adding the actual work area links to this analysis, a more complete picture of traffic through the spacecraft is obtained. Composite flow paths typical of a work day are shown in figs. 4-24 and 4-25 for different stacking of the modules that make use of a central passageway. Using a central passage has two distinct disadvantages: traffic in opposite directions must pass in confined quarters; and safety exits are not provided. Also, a single tube passage may be hazardous because a fire flash could travel through the entire spacecraft via this tube.

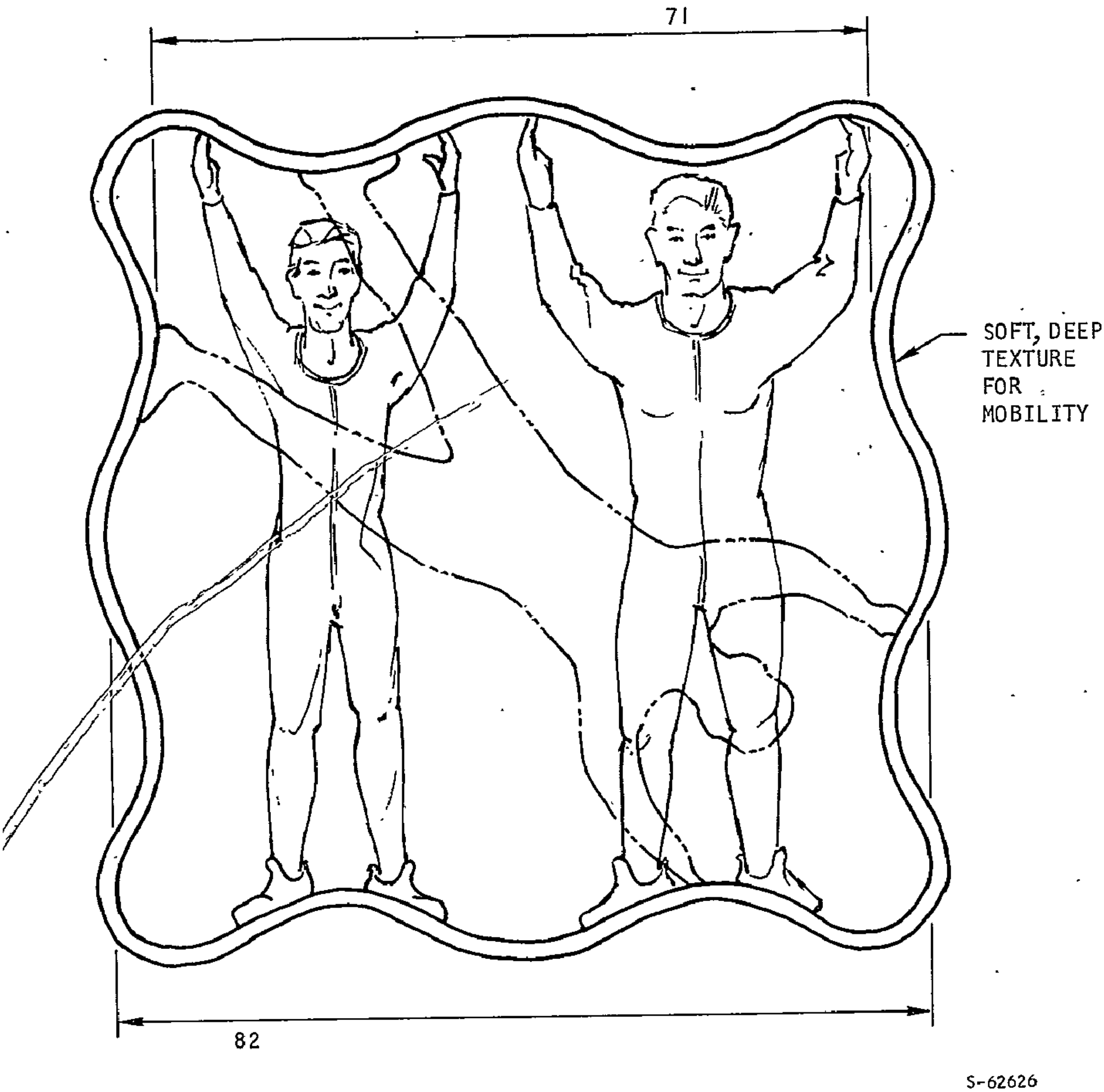
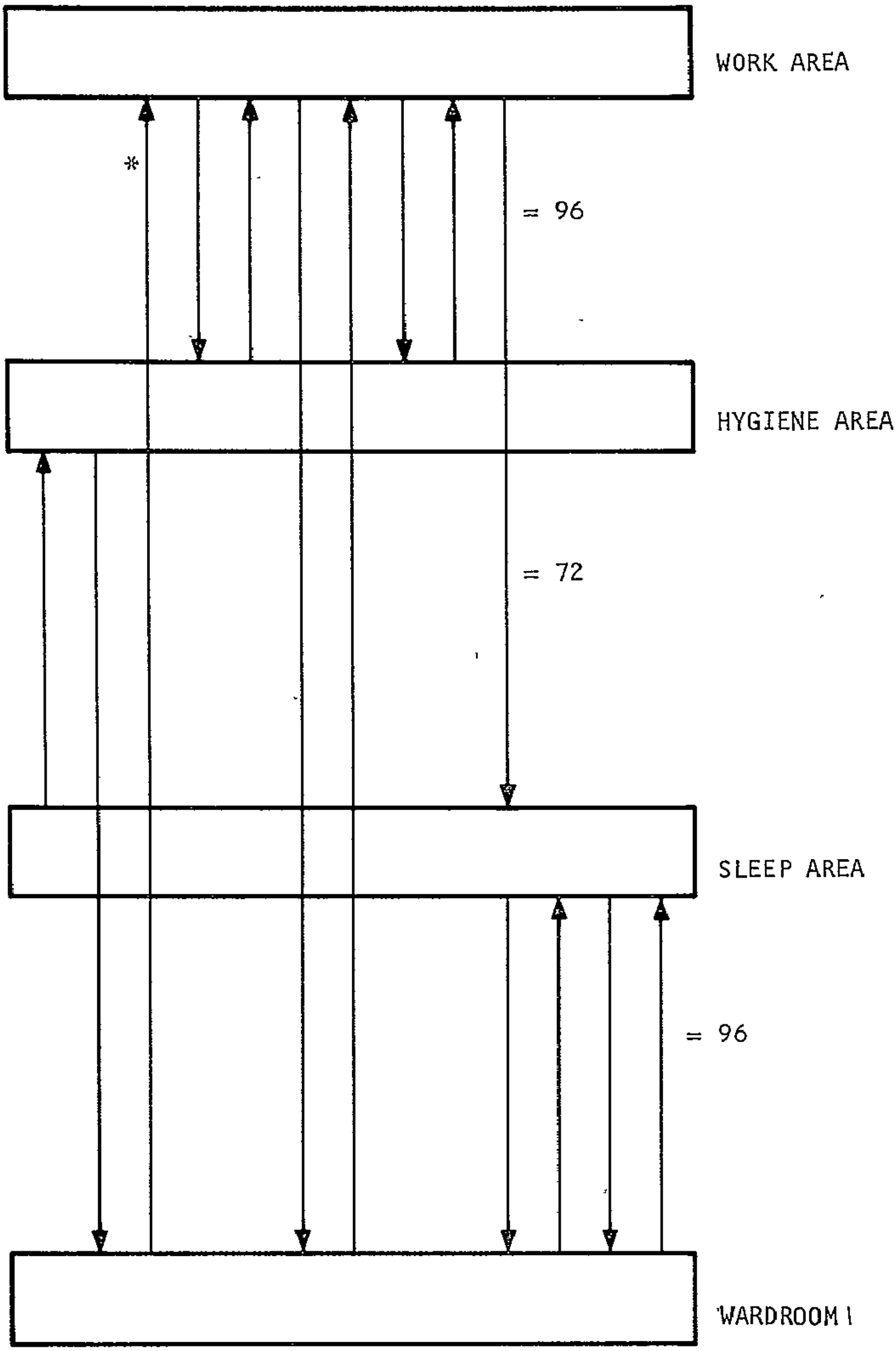


Figure 4-19. Contoured Passageway Concept



*12 CONTACTS EACH LINE

1716 FT TRAVELLED

S-62634

Figure 4-20. Space Station Traffic for Plan I Compartment Layout

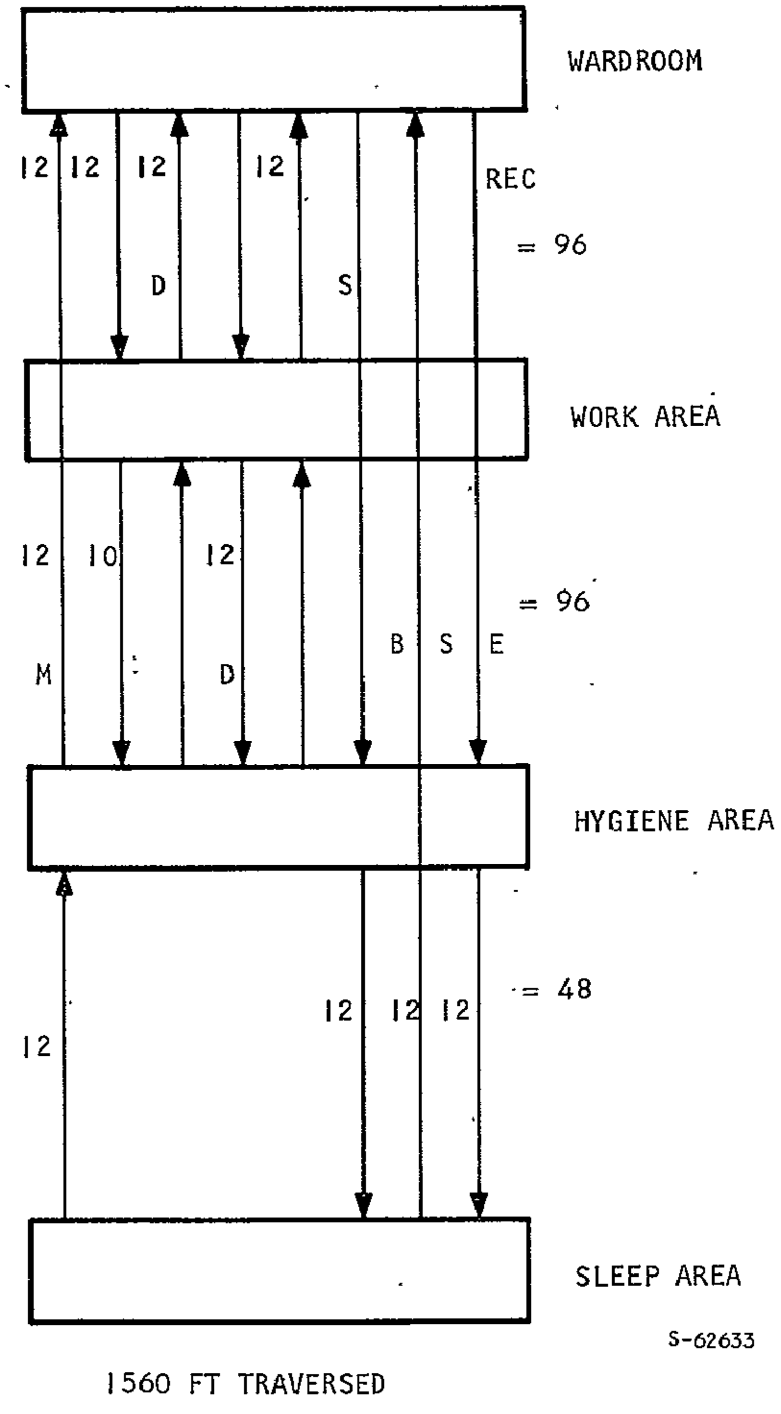
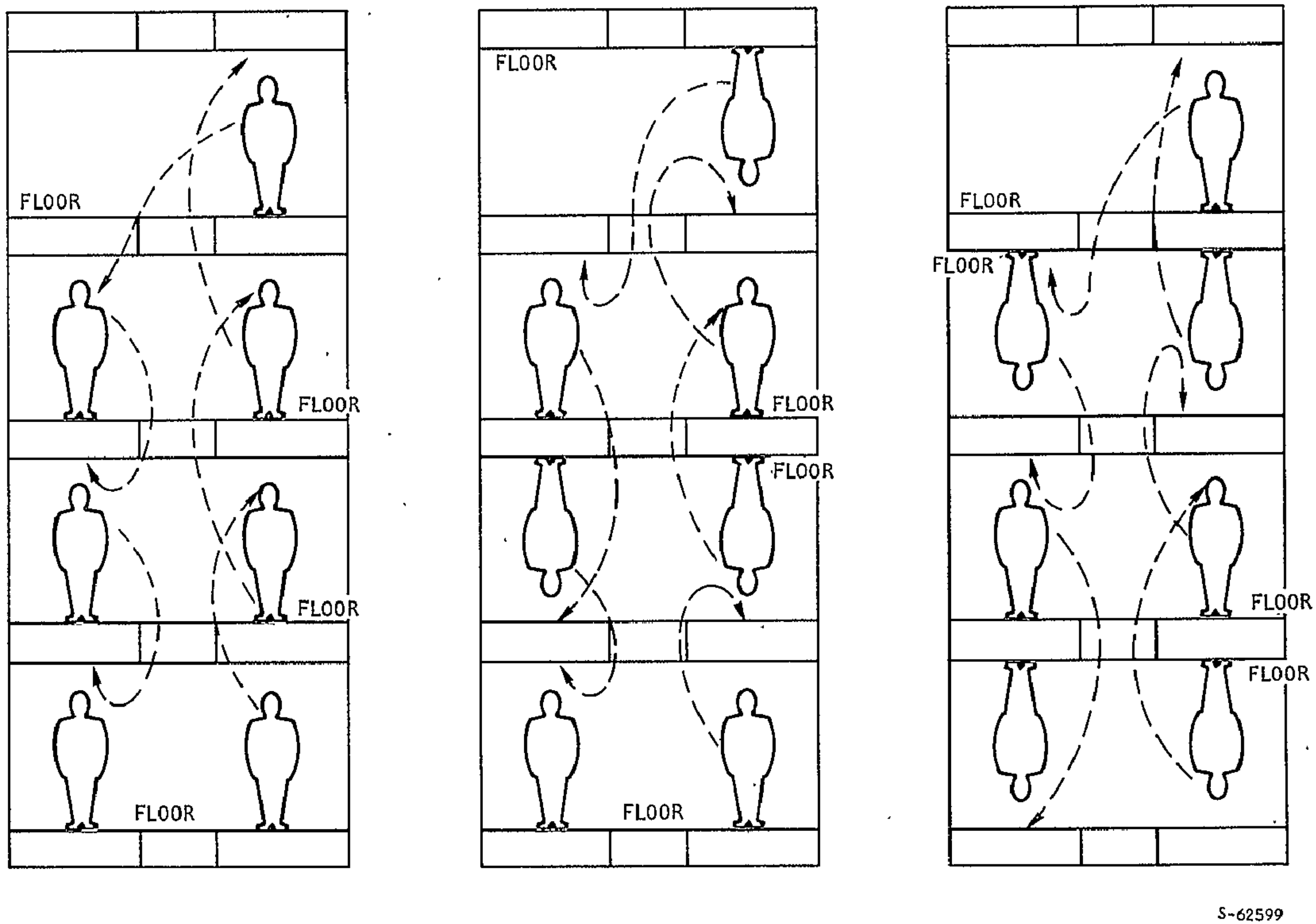


Figure 4-21. Space Station Traffic for Plan II (Best) Compartment Layout



A

FLOORS ALL IN SAME DIRECTION

B

FLOORS ON THE ENDS AND MIDDLE

C

FLOORS BACK-TO-BACK INBOARD

Figure 4-22. Comparison of Floor Arrangements for Maneuverability

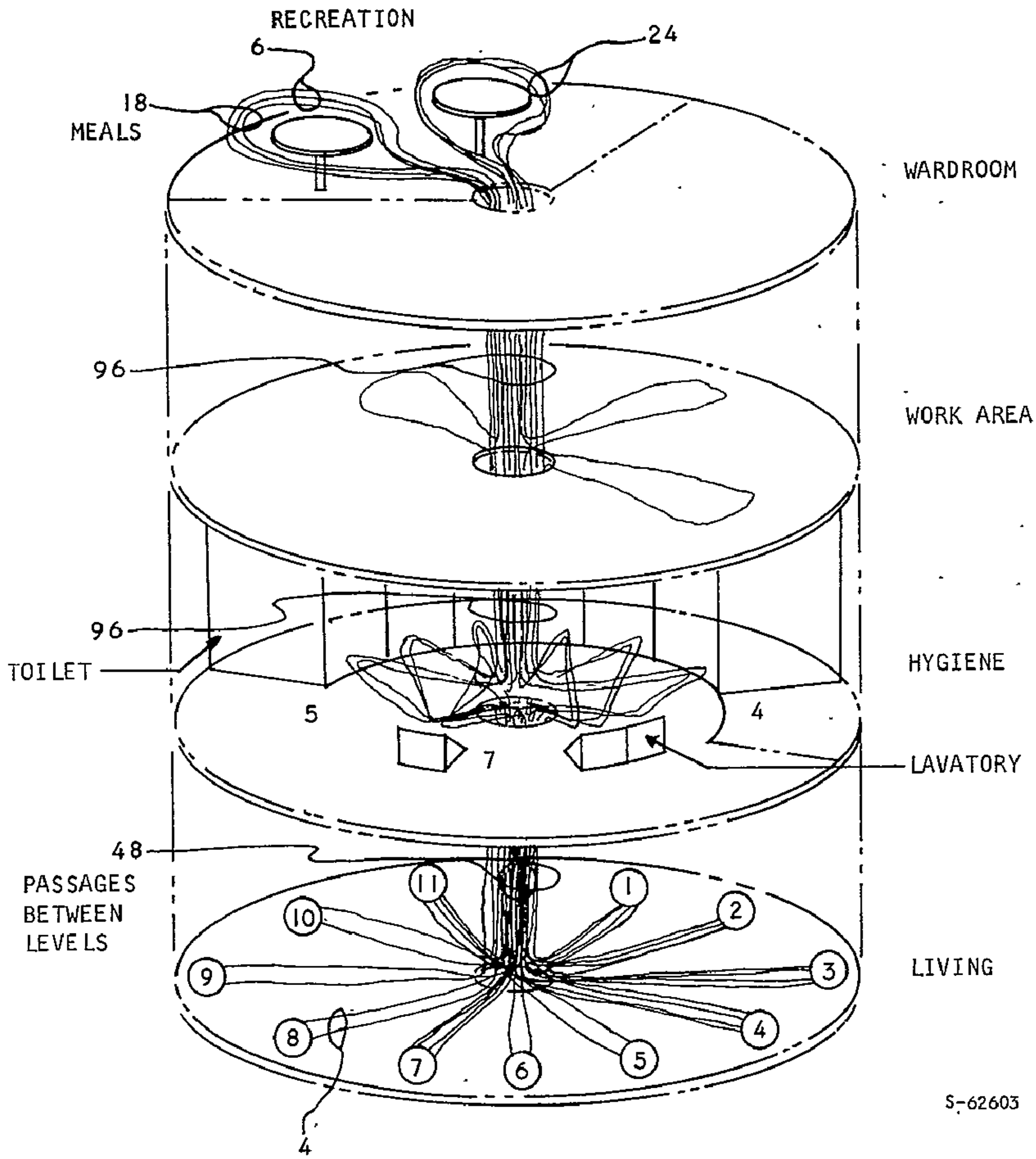


Figure 4-23. Center Passageway Flow Diagram for Typical Work Day

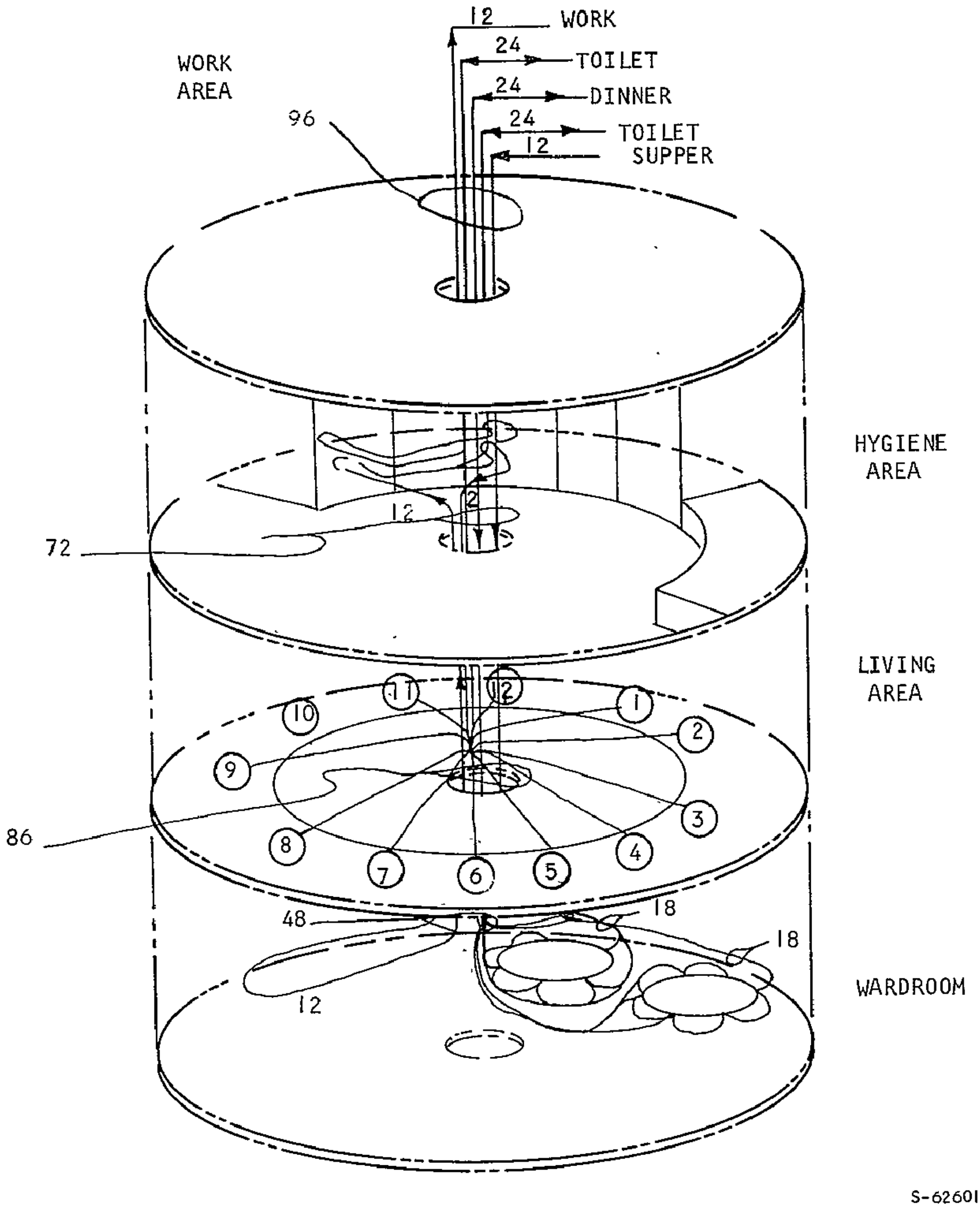


Figure 4-24. Center Passageway Composite Flow During Typical Work Day

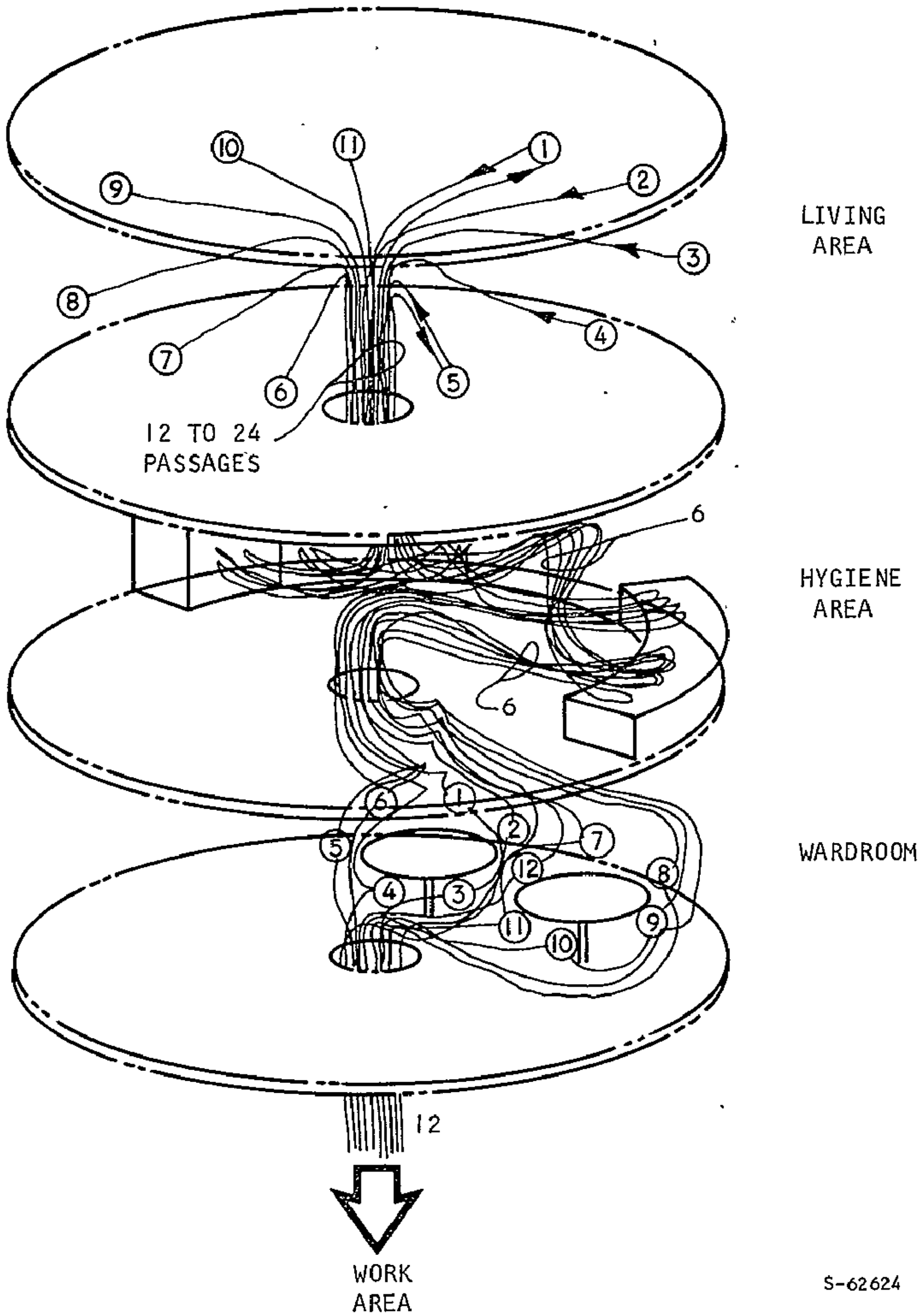


Figure 4-25. Center Passageway Flow Diagram for Start of Duty Cycle

The dual passageways shown in figs. 4-26 and 4-27 provide one-way traffic through the spacecraft, which results in a smoother traffic pattern, improves mobility, and reduces the danger of free-flight collision. Two hatches are located on each floor to provide an alternate exit in case of emergency. Providing dual passageways through the spacecraft offers advantages that should be investigated, especially for growth potential. Modular attachments to the spacecraft may be more flexible, better structurally, and negotiated by the crew more easily.

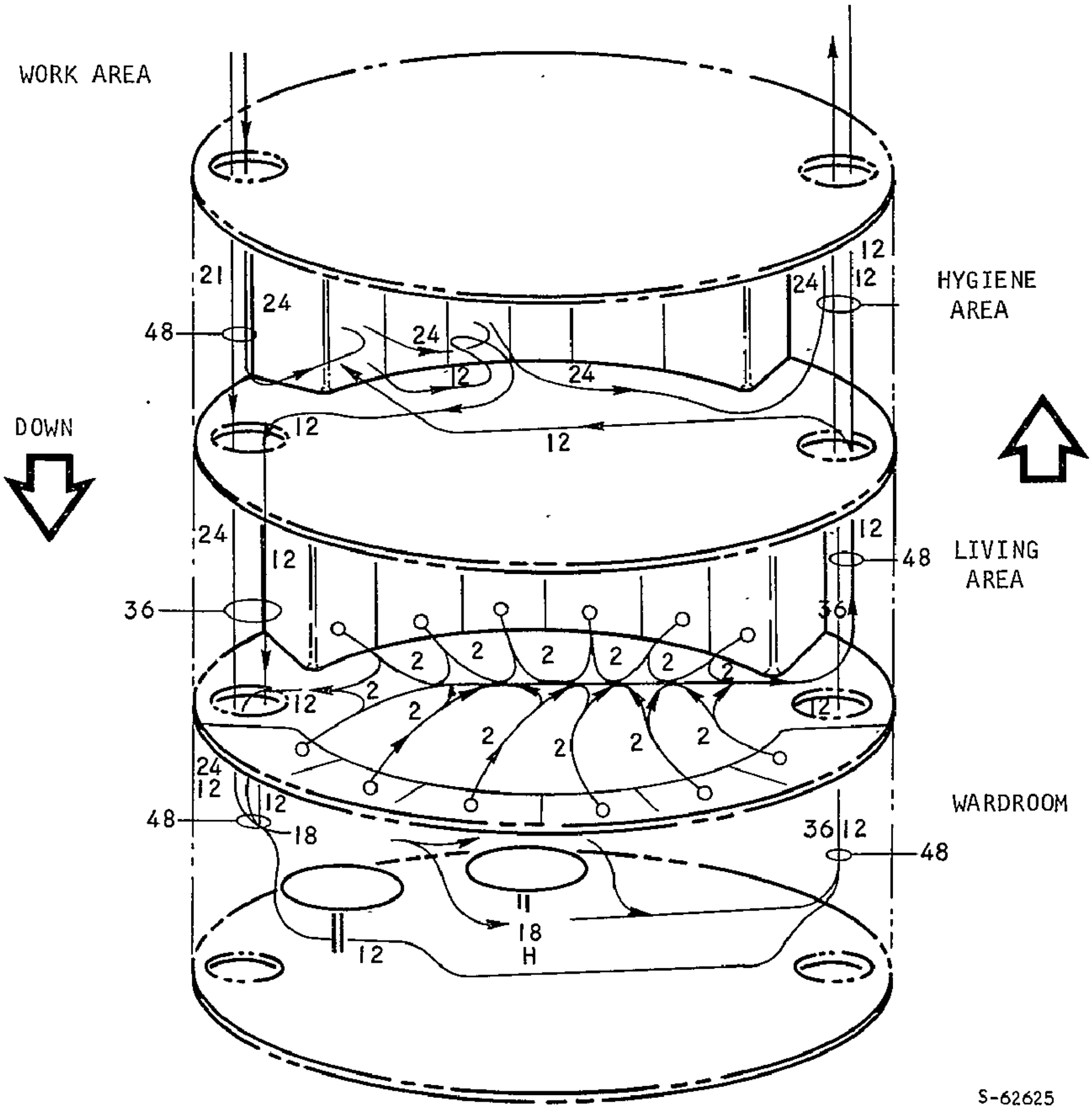


Figure 4-26. Dual Passageway Composite Flow During Typical Work Day

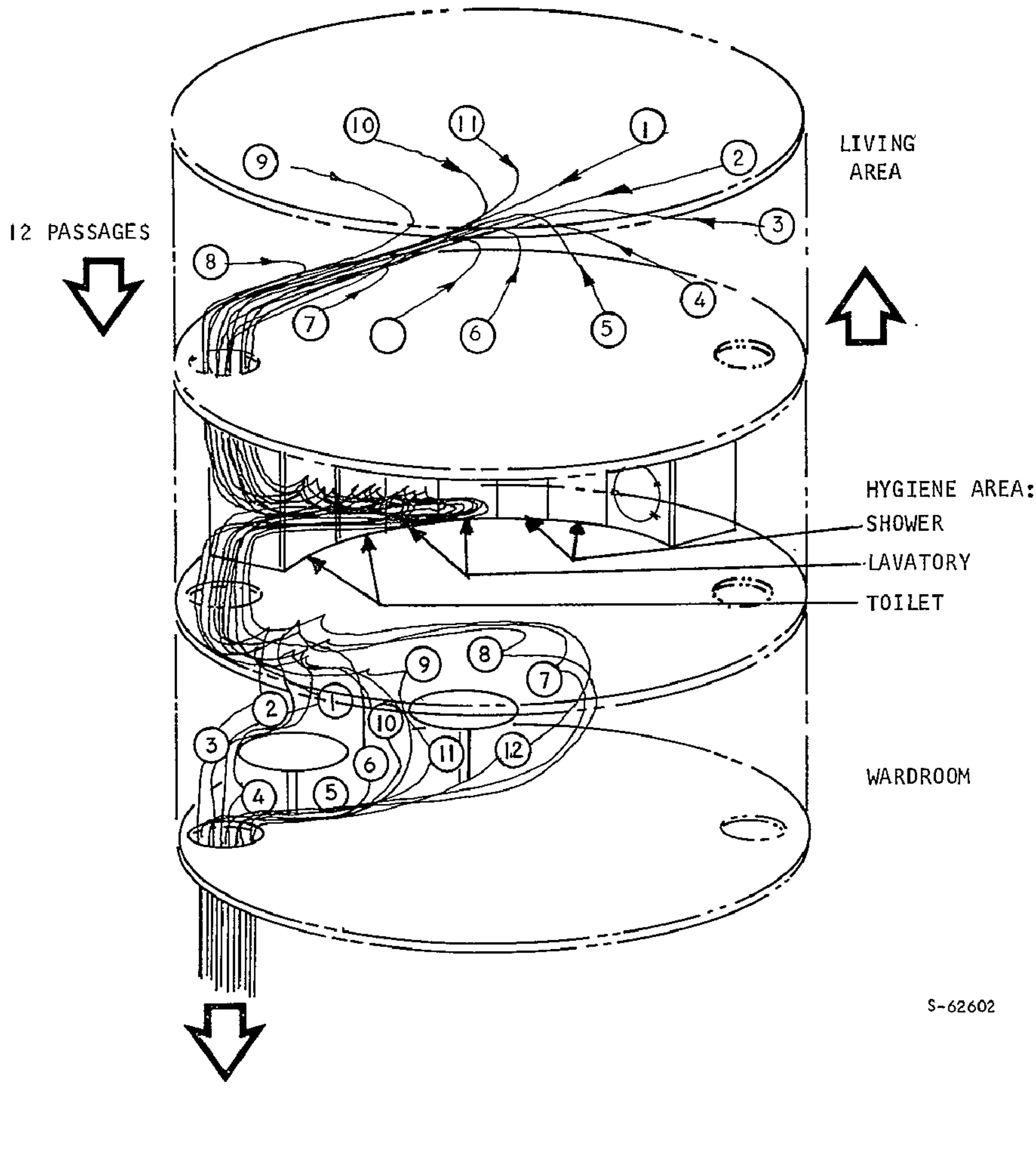


Figure 4-27. Dual Passageway Flow Diagram for Start of Duty Cycle

SECTION 5

COLOR AND ILLUMINATION FOR PERCEPTUAL RICHNESS AND TASK PERFORMANCE

5

COLOR AND ILLUMINATION FOR PERCEPTUAL RICHNESS AND TASK PERFORMANCE

PROVIDING PERCEPTUAL RICHNESS

Perceptual richness is the sensible variety offered by a given ambient. One method of providing perceptual richness is to vary the color, texture, and illumination of the surroundings. This can be done more easily if the basic interior color is white. White will pick up and reflect colors from the lights, act as a space expander, and provide a good background for bright color accents.

Interchangeable modular panels that are white on one side and covered with materials of different colors and textures on the other can be used to change the appearance of the interior. The panels can be moved from one compartment to the other to provide a wide selection of interior color schemes and a wide variation in surface textures.

Other simple techniques for providing perceptual richness include the application of dichromatic paint to various components. This technique provides visual richness by apparent changes in the color of the object as the observer's perspective changes. Forms are enhanced by this technique; the edges appear bold against one background and then become soft as the color shifts to match the major area. This technique is illustrated in figs. 5-1 and 5-2. Fig. 5-1 shows a model of the microwave oven finished with dichromatic paint as viewed from above (normal standing position). From this point it appears as a warm tan or earth color. When viewed from the sitting or operating position (fig. 5-2), the top of the oven changes to a cool green along the periphery.

Another method of providing visual richness through the surface finish applied to objects is shown in fig. 5-3. In this example, a black waterdrop finish is applied to the audiovisual viewer. The surface normal to the line of sight presents the water drops in a dramatic fashion, while the other surfaces appear black. As the observer changes his relationship with the viewer, the waterdrops seem to move from surface to surface.

Two recent discoveries that offer promise in promoting perceptual richness are ferroelectric ceramics and liquid crystals. Ferroelectric ceramics change color when a voltage is applied and can be made in thin chips. Liquid crystals change color with temperature, and some change color when an electric field is applied. Both of these materials are new but should be investigated for use in providing visual richness in future spacecraft.*

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* Product Engineering, June 22, 1970
Volume 41, No. 12, McGraw Hill P-18
Ferroelectric Ceramics: Tomorrow's Color-Imaging Method Today.

Figure 5-1. Microwave Oven Viewed from Above-
Top Appears Tan in Color

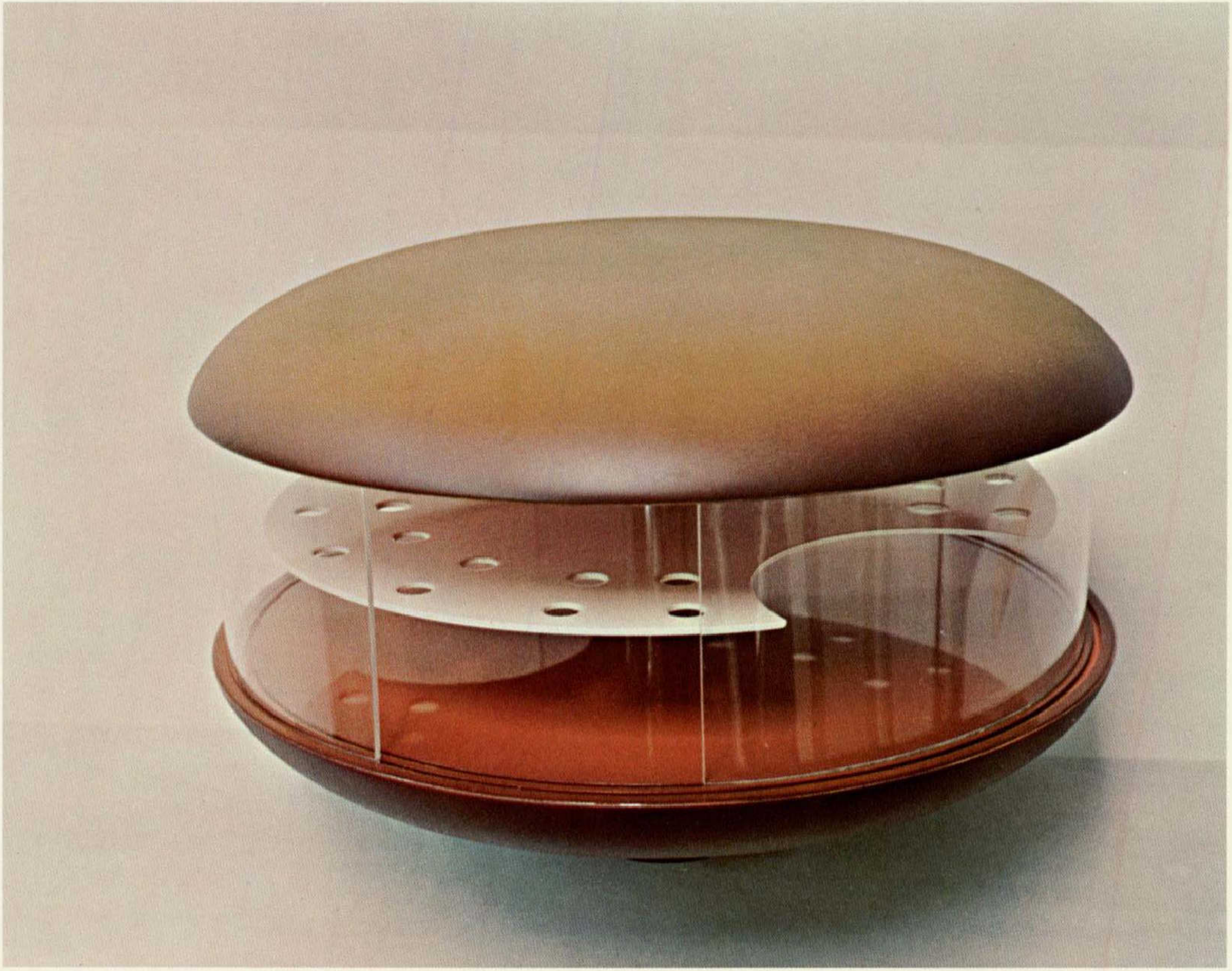

Figure 5-2. Microwave Oven Viewed from the Seated or Operating Position - Top Appears Green

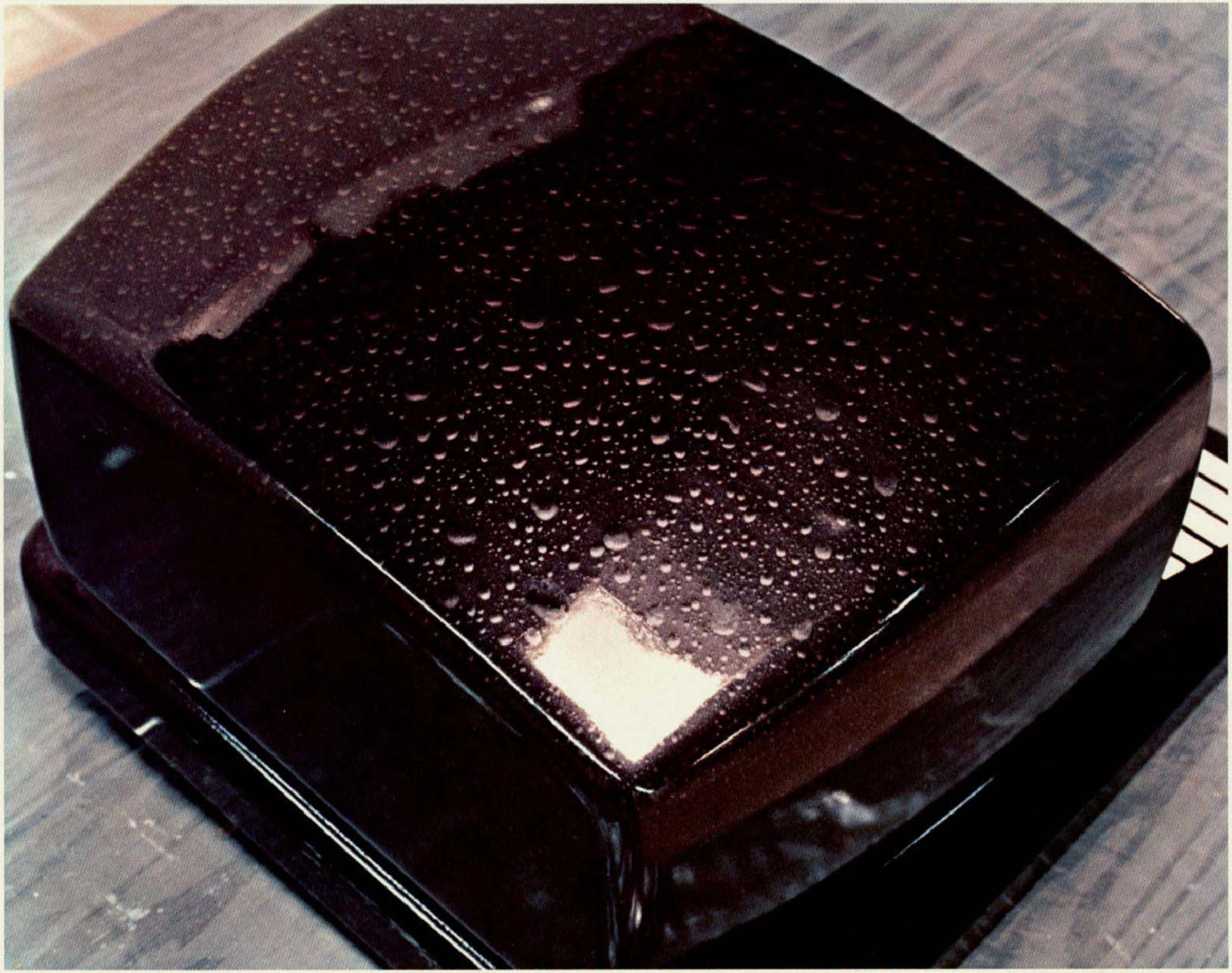

Figure 5-3. Waterdrop Finish on Audiovisual Viewer

Illumination also can be used to provide perceptual richness. For example, illumination in the sleep compartment would be from two sources, ambient and local. Ambient lighting can be from a source inside or outside the compartment.

To evaluate the interior lighting for a sleeping compartment, two fluorescent tubes were recessed, one on each side of the arbitrary ceiling, to conceal the light source (fig. 5-4). The units were designed so that colors and intensity could be changed to suit the individual. A wide variety of colors ranging from warm to cool to white becomes available as the multicolored filters around the fluorescent-tubes are rotated. Colors can be mixed by holding the color selected on one lamp constant while the other filters are rotated until the desired color mixture is obtained. With the white interior, various surfaces reflect the different colors impinging upon them and give the appearance of a multicolored interior. Pleasing effects are achieved by use of various combinations, and the effects can be changed to suit various moods.

For the exterior source of ambient illumination, a translucent sliding door on the front of the compartment is used to provide a soft diffused light within the compartment; an opaque sliding door (fig. 5-5) shuts out the light for sleeping. The compartment provided by these sliding-door ambient lighting systems is approximately 10 ft long and 10 ft wide. A corridor view of the different door arrangements is shown in fig. 5-6. The gold and blue panels on the left and right sides are opaque doors that are closed. The second door from the left is the translucent door illuminated from within the sleeping compartment. The open bay shows a sleeping compartment entrance with both doors open.

The translucent door permits illumination on both sides while maintaining privacy for the occupant. Soft diffused illumination of the sleep station is provided from the corridor lights and can be reduced or completely eliminated by closing the opaque door. Corridor illumination is also enhanced by the lighting from within the sleep compartments. Figs. 5-7 through 5-15 illustrate the various effects that can be achieved in the sleeping compartment by the internal and external lighting arrangements described above. The effects of different lighting on colored panels made of various materials is shown in figs. 5-16 and 5-17.

A small portable lamp (fig. 5-18) must be provided within each sleeping compartment to provide higher local illumination levels for activities such as reading.

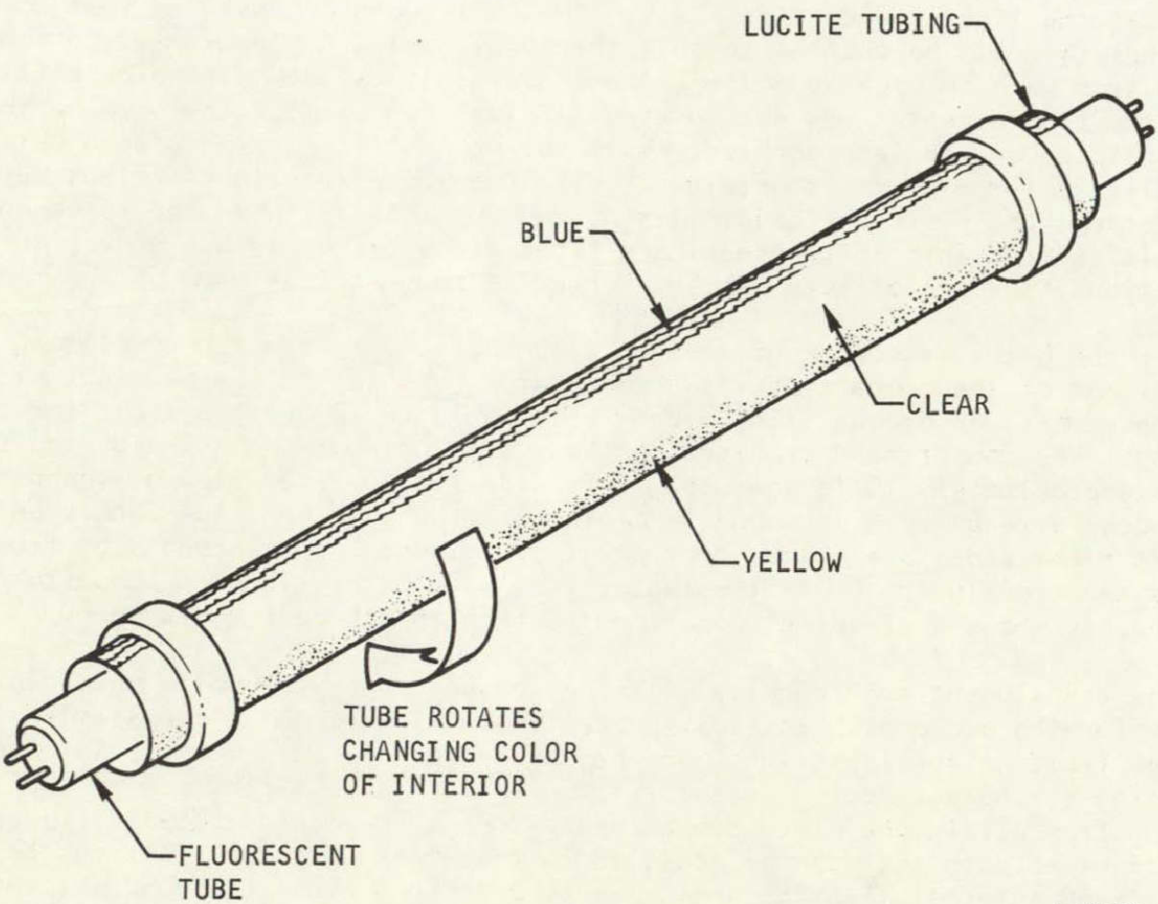

Figure 5-4. Apparatus Used to Vary Lighting

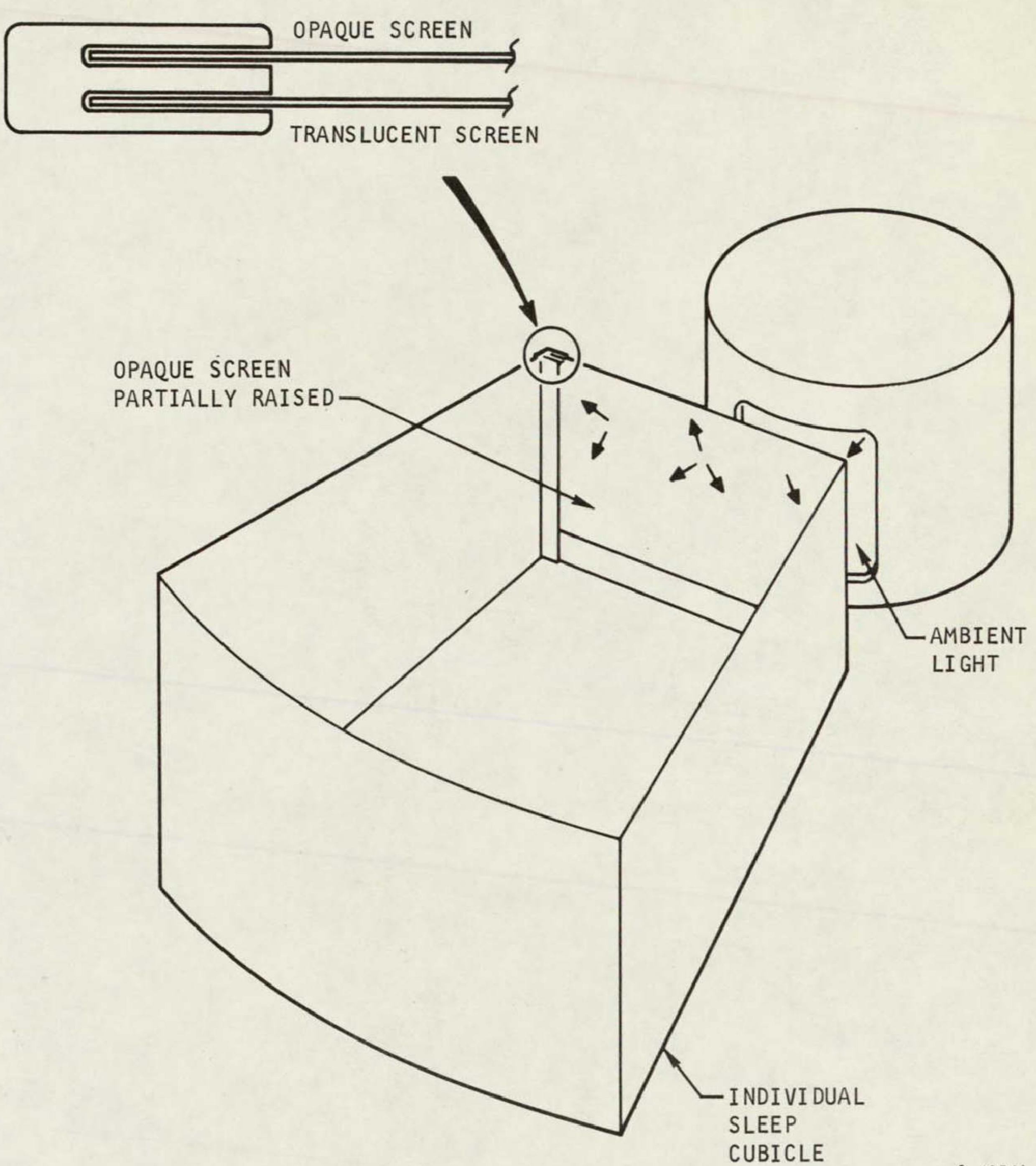

Figure 5-5. Ambient Light Screening Technique

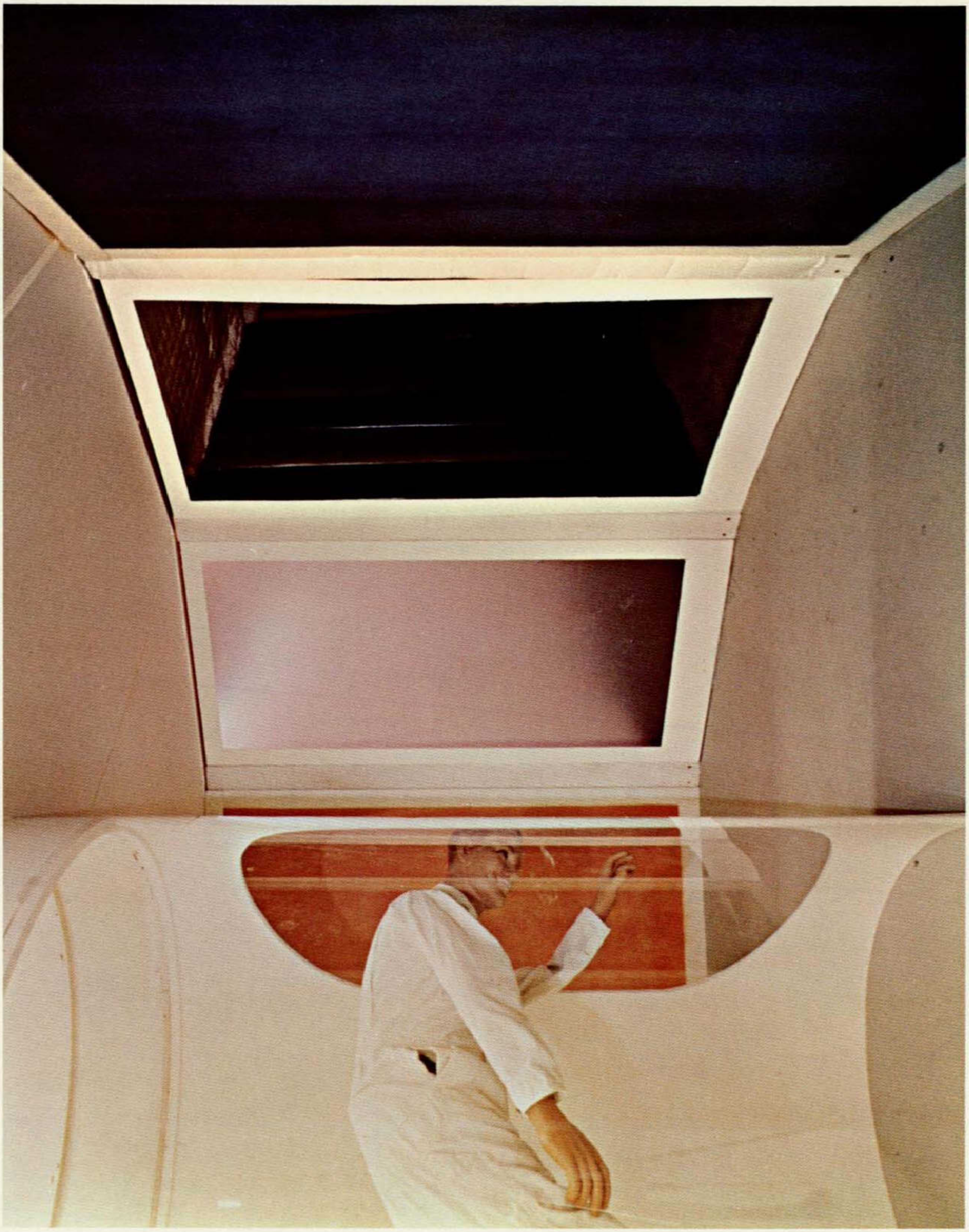

Figure 5-6. View Showing the Various Door Arrangements

Figure 5-7. White Interior and Exterior Lighting

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Figure 5-8. White Interior and Subdued Exterior Lighting

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Figure 5-9. Mixed Warm and Cool Interior Lighting

Figure 5-10. Warm Exterior (Yellow) with Minimum Cool (Blue) Interior Lighting

Figure 5-11. Warm Interior and Cool Exterior Lighting

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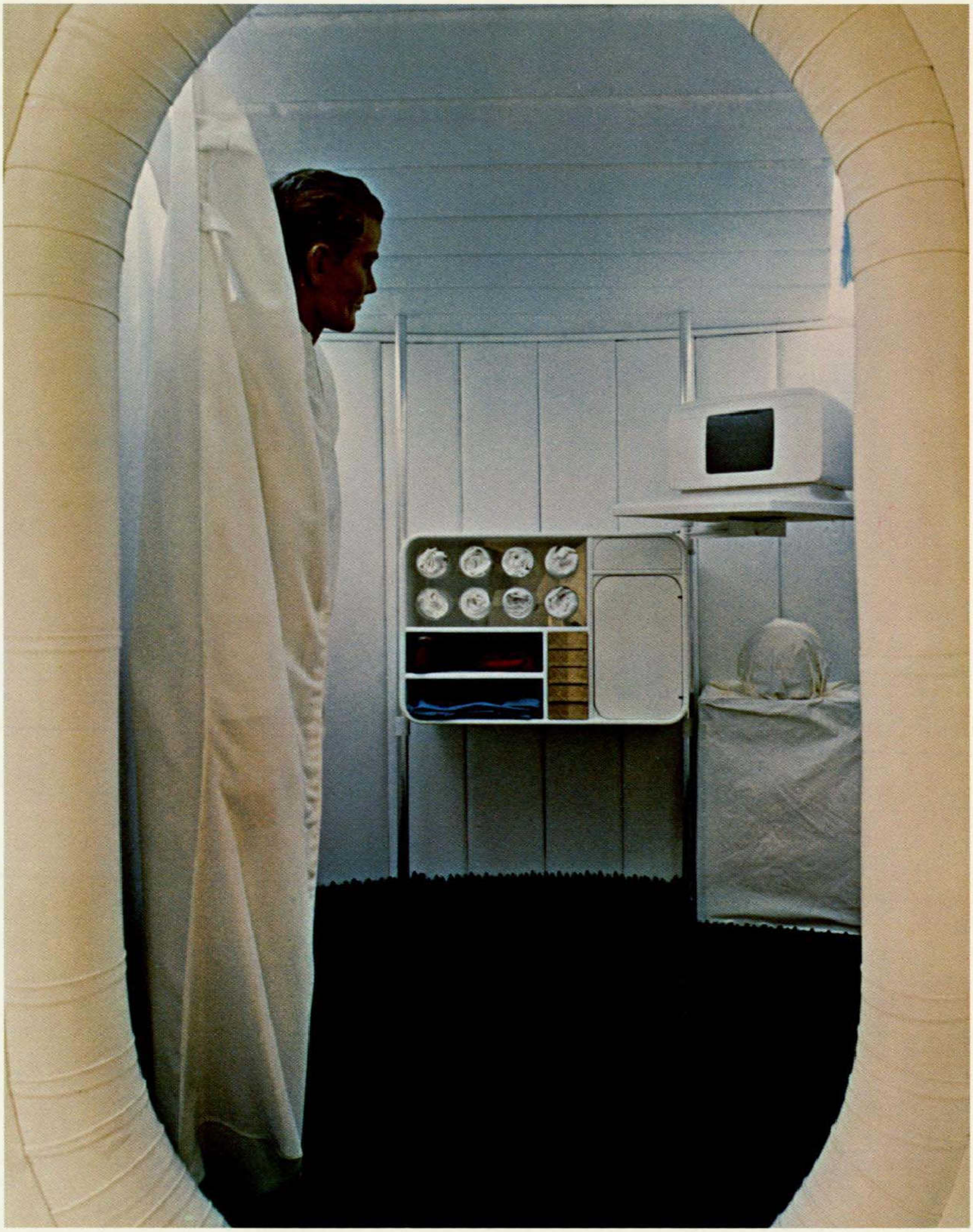

Figure 5-13. Cool Interior Lighting

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Figure 5-14. Cool Interior and Exterior Lighting

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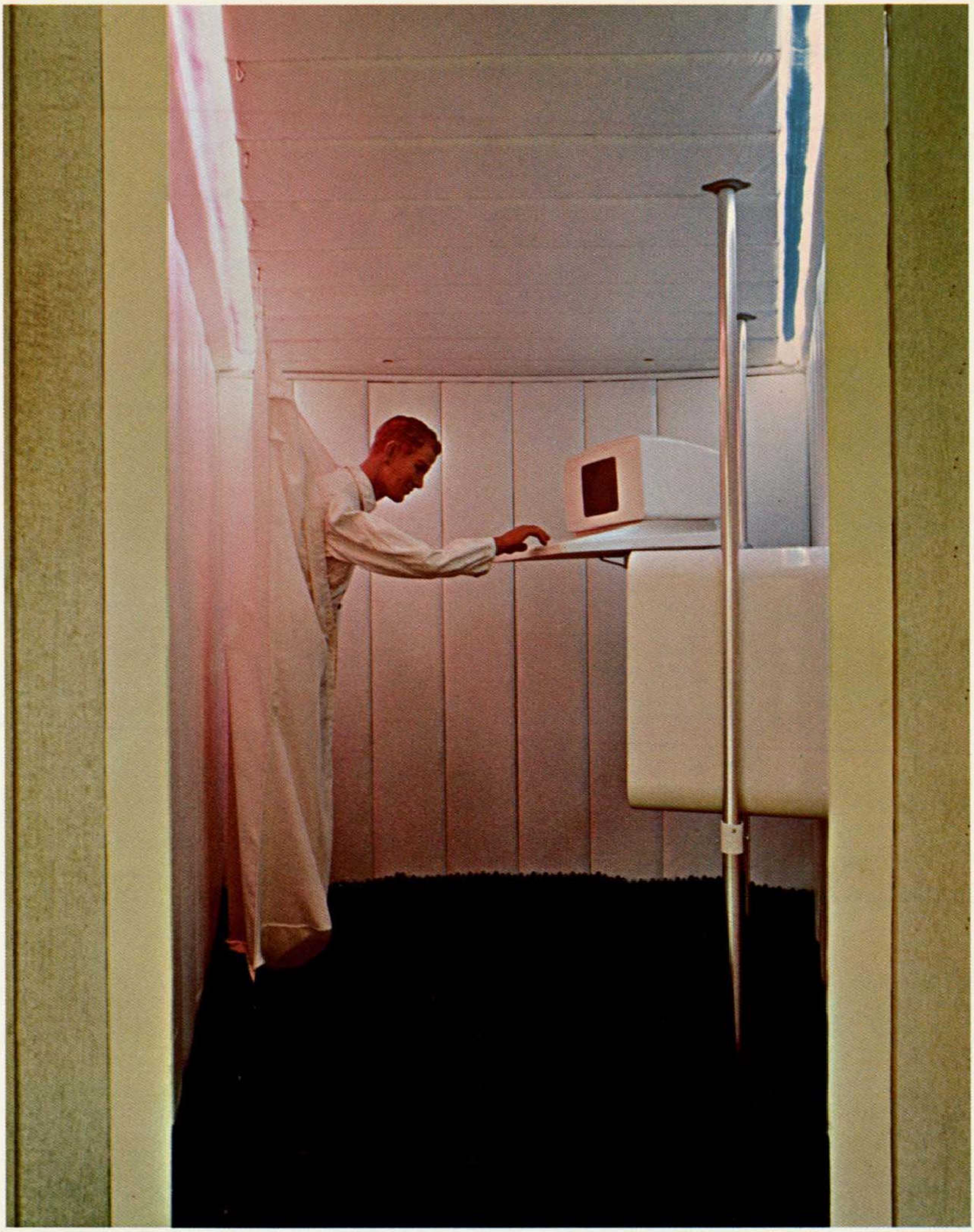

Figure 5-15. Mixed Warm and Cool Interior Lighting with Cool Corridor Lighting

Figure 5-16. Cool Light on Colored Panels

Figure 5-17. Warm Light on Colored Panels

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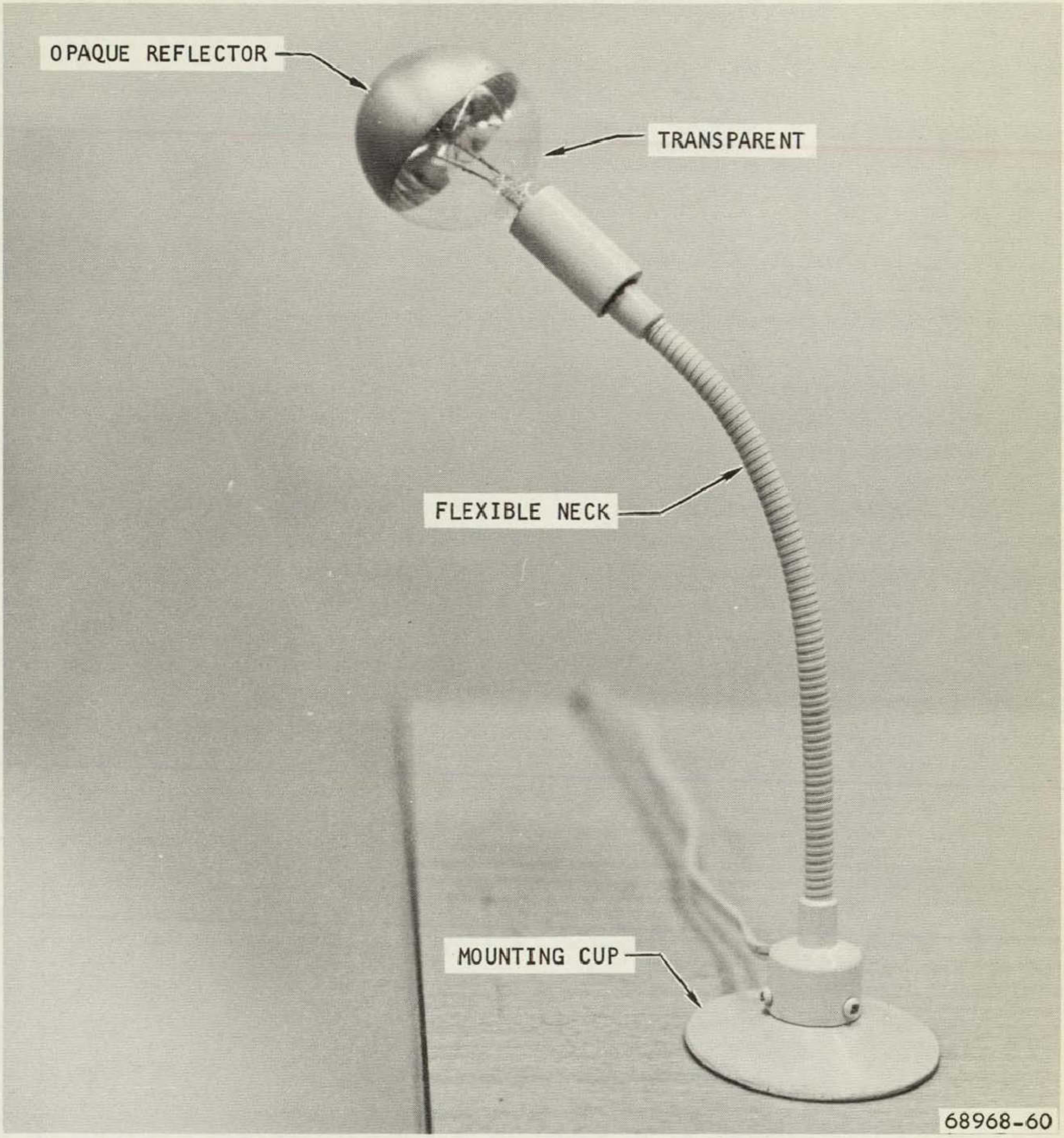

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Figure 5-18. Portable Local Light Source

ILLUMINATION FOR VISUAL TASKS

General design philosophies recommended as guides in the development of lighting criteria are based on visual performance requirements, and therefore are directly related to crew functions. Visual task requirements for this document are concerned with those tasks associated with the wardroom, sleep area, and hygiene area. These tasks include reading, food preparation, eating, handwriting, maintenance, exercising, playing games, sleeping, talking, personal cleanliness, and self-relief.

While insufficient illumination may be an obvious contributor to the degradation of performance, too much light in the form of glare or an adequate amount of illumination improperly applied also may have the same effect. Illumination levels required for various tasks accomplished in the same areas are different; therefore, it is practical to include intensity controls or supplemental lights in these specific areas.

Recommended illumination levels and problems associated with them for general applications are provided in NASA Publication MSFC-STD-267A dated September 23, 1966. A list of general illumination requirements from the referenced NASA publication is included as table 5-1. Specific recommendations from these general illumination requirements are included as table 5-2.

TABLE 5-1

GENERAL ILLUMINATION REQUIREMENTS

Task Conditions	Illumination at Work Point, ft-c
Rough seeing tasks Inactive storage, hallways, large objects	1 to 5
Casual seeing tasks Active storage, service areas, stairways	5 to 10
Visual tasks comparable to reading 10- or 11-point print on good quality paper (i.e. good legibility)	10 to 15
Visual tasks comparable to reading newsprint	15 to 20
Ordinary seeing tasks involving moderately fine detail with normal constraints Reading, handwriting, ordinary bench and assembly work	20 to 30

TABLE 5-1 (Continued)

Task Conditions	Illumination at Work Point, ft-c
Visual tasks requiring very fine discrimation, small detail, fine finishing, fine assembly	30 to 50
Difficult visual tasks with poor control and precision requirements Extra fine finishing or assembly under low brightness contrast conditions	50 to 100

TABLE 5-2

SPECIFIC ILLUMINATION RECOMMENDATIONS

Task	Illumination at Work Point, ft-c
Map and chart reading	30
Performing calculations	15 to 20
Preparing reports	15 to 20
Cleaning compartments	5 to 10
Maneuvering in area	1 to 5
Entering and leaving compartments	1 to 5
Reading for pleasure	15 to 20
Playing recreational games	15 to 20
Preparing food	10 to 15
Eating food	10 to 15
Self-relief	1 to 5
First aid	60 to 100
Personal cleanliness	10 to 15
Emergency repair	30 to 50
Operating controls	20 to 30

SECTION 6

ENVIRONMENTAL CONTROL CONSIDERATIONS

6

ENVIRONMENTAL CONTROL CONSIDERATIONS

The long duration of the space station mission imposes the following important requirements and constraints on the definition of the environmental control/life support system (EC/LSS):

(1) The assurance of mission success and crew safety. This can be achieved only through the synthesis of a maintainable system.

(2) The efficient use of the crew throughout the mission. This requires that maintenance actions be reduced to a minimum so that maximum time is available for experiments and ample time is provided for crew personal and social activities. The space station arrangement and facilities must be designed to satisfy the crew physiological and psychological requirements. Such arrangement imposes important constraints on the EC/LSS design.

(3) A weight-optimized EC/LSS. Tradeoff studies must be performed and system/subsystem functions selected. These studies should indicate that water and oxygen recovery should be incorporated in the design. The present investigation is concerned with the impact of habitability on these subsystems.

EC/LSS DEFINITION

A number of functions related to space station habitability must be examined to determine the constraints imposed by these functions on EC/LSS design and overall system arrangement. Table 6-1 presents a summary of typical functions and identifies the life support techniques recommended for each life support function considered. Figure 6-1 illustrates the arrangement of the EC/LS subsystems in a typical four-compartment space station. Packs should be provided on each side of the pressure bulkhead to permit reentry in a depressurized state and allow repair of a puncture or other malfunction. Significant subsystem/system factors that must be considered in designing a space station are discussed below. The recommended approaches are preliminary.

ATMOSPHERE CONDITIONING

In general, all environmental control functions will be performed in central processing subsystems. Ducts will carry cool conditioned air to the various space station compartments and rooms. Each room will have an independent temperature control which will maintain the temperature in any particular area at the selected value by varying the ventilation flow rates.

TABLE 6-I
EC/LSS DEFINITION

Compartment	Function	EC/LSS Constraints	Recommended Technique
Personal	Sleep	Lower metabolic rates, thus lower ventilation rates, low noise level	Separate room temperature and ventilation control. Location of sleeping compartment remote from noisy equipment.
	Separation and isolation	Odor problems	Filters on return ducts.
		Bacteria control	Complete isolation not established as a requirement.
		Special experiment requirements (pressure, temperature)	Special ECS provisions charged to experiment and designed specifically to satisfy experiment requirements. Such equipment not considered part of ECS.
	Personal leisure activities	Possibly wide range of activities	Ventilation rate adjustable over wide range.
	Dressing	No specific requirement	
	Grooming	Hair cutting, shaving will be required	Vacuum collector, lavatory, waste disposal provisions.
	Storage of personal effects	N/A	
	Space suit storage	Drying after use, ventilation	Use ambient air with fan for drying. Space suit storage area should be well ventilated with relatively dry air.
Hygiene Area	Defecation	Feces collection Odor control Astronaut cleanliness Feces processing	Pneumatic toilet with air recirculated through charcoal filter. Feces collected in toilet which is evacuated to space when not in use. Volume sufficient to accommodate crew size for resupply period. Vacuum drying chamber replaced when full. Dried feces completely deactivated by heating under vacuum when collection chamber is full; tank is brought back to Earth. Anal water flush - recovered with urine.
	Urination	Urine collection	Diaphragm and urinal with air flow.
		Odor control	Air flow recycled through filter.
		Bacteria control	Water flush with periodic addition of bactericide.
		Water recovery	Vacuum distillation with vapor pyrolysis (central unit) - concentrated brine stored in replaceable tanks.
	Waste disposal	Trash collection	Manual.
		Trash disposal	Stored in vacuum chamber. Trash is compacted and stored in evacuated chamber. Trash which is conducive to bacterial growth is sterilized at 230°F before storage. Residue from water recovery process is stored in separate tank. This tank is brought back to Earth.

TABLE 6-1 (Continued)

Compartment	Function	EC/LSS Constraints	Recommended Technique
Personal Hygiene	Washing	Water (hot and cold) Shower Skin drying Face and hand wash	Wash water recovery by reverse osmosis and temperature controlled spray nozzle shower with sump pump to recycle soapy and rinse water with hot air and/or towels - separate condenser required, also air heater (could be integrated with thermal control "zero-G lavatory") - wash cloth and/or sponges may be used as grooming aids.
	Grooming	Potable water required	Zero-G lavatory.
		Particulate matter collection (hair, nail clipping)	Vacuum collector.
		Odor removal	In central ventilation system.
		Debris - trash	Waste collection provisions.
	Oral hygiene	Potable water	Cold potable water - ingestible dentifrice or "zero-G lavatory" with air entrainment.
	Laundry	Wash water	1 lb/man-day of laundry.
		Clothes drying	Water recovery by reverse osmosis. Clothes drying by air evaporation using cabin air and separate condenser with fan.
Wardroom	Social interaction	Temperature	Adjustable ventilation rate.
	Eating	Food storage	Dried and frozen food diet - freezer/refrigerator required.
		Food reconstitution	Potable water required (hot and cold).
		Food preparation	Cooking facilities: oven.
		Residue and waste storage	Manual.
		Residue and waste storage	Sterilization and storage in evacuated trash chamber.
		Odor removal	Probably separate charcoal filter in kitchen area.
	Leisure activities	N/A	Selectable ventilation rate.
	Briefing/debriefing	Concentrated metabolic load	Adjustable ventilation rate.
	Drinking	Cool water	Cooling source from thermal loop.
	Food preparation	(See above)	
	Waste disposal	(See above)	
	Medical disposal	Bacteria control	Manual - vacuum storage following sterilization of water when required.
	Medical care		
	Exercise		Adjustable ventilation rate.

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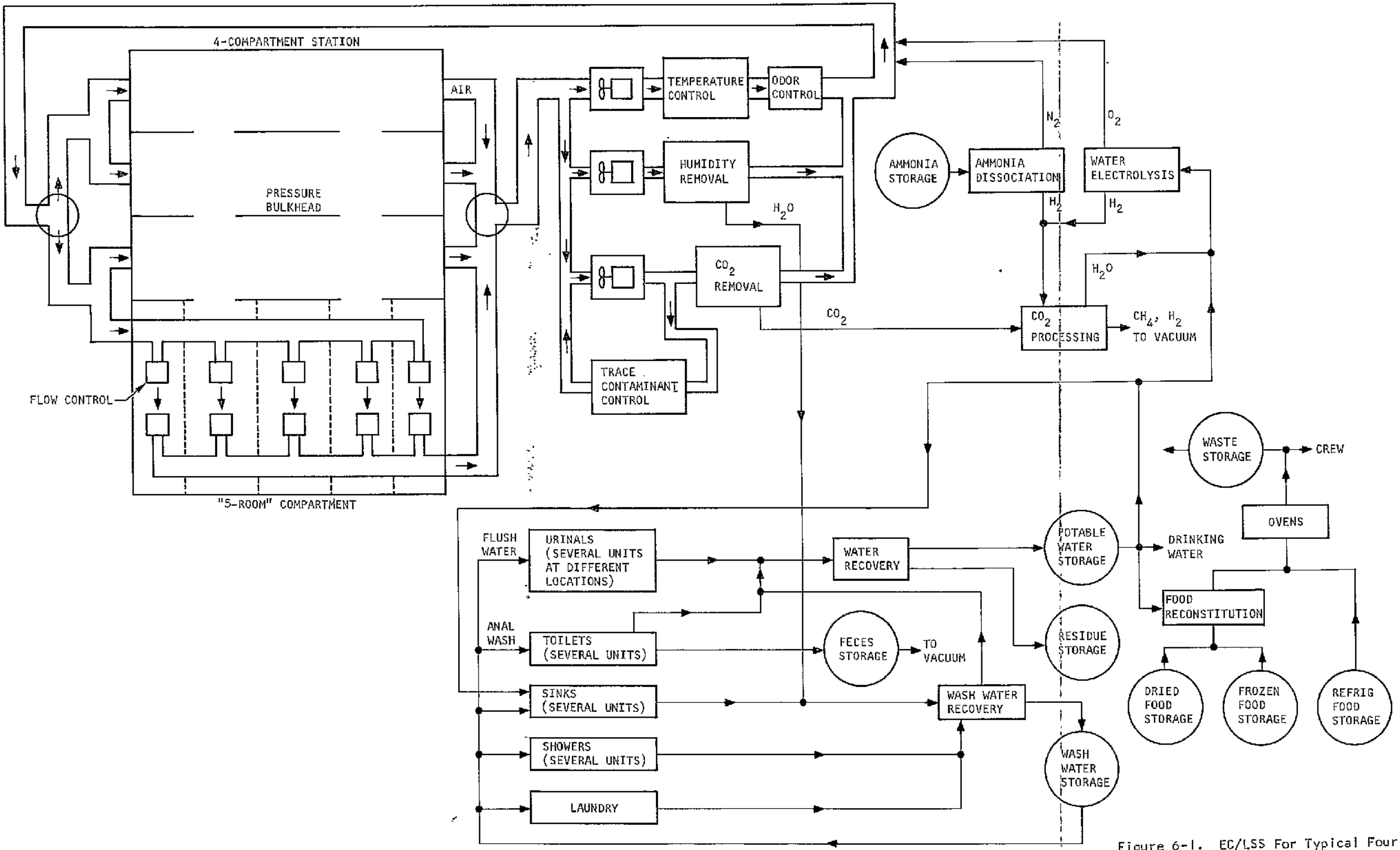

Figure 6-1. EC/LSS For Typical Four-Compartment Space Station

FOLDOUT FRAME 1

FOLDOUT FRAME 2

In areas where equipment loads are small and metabolic activities are low, adequate ventilation for contaminant removal must be provided although the net heat load might be negative; thus temperature and ventilation control must be separate. This implies the use of regenerators between the compartment (or room) inlet and outlet air. Such areas include the staterooms, which might reach unacceptably low temperature levels when unoccupied and the toilet-shower room. Detailed investigations are necessary to determine where regenerators will be required or whether heating is a requirement.

A room will be provided for partial isolation of sick astronauts; complete atmosphere isolation may be a requirement because of the unknown effect of abnormal atmosphere on normal bacterial flora of man. Filters that will remove odors and prevent bacteria from spreading throughout the space station will be used on the inlet and outlet vents of the isolation room.

It is possible that some experiment will require that the atmosphere of the compartment or experimental chamber be isolated from the rest of the station because of (1) generally higher or lower temperature level requirements, (2) high contaminant production rates, or (3) different atmospheric composition or pressure. Special equipment will be necessary to handle the requirements imposed by such experiments. This equipment should be considered a penalty to the experiment itself and will not be included as an integral part of the basic EC/LSS.

Because of the nature and the amount of odors generated in the kitchen area, a separate recirculation loop including a fan and a charcoal filter is recommended. Such equipment will greatly extend the life of the main system odor filter.

The toilets and urinals will use air for propelling the feces and urine. This air will be filtered through sorbent beds before being exhausted to the cabin. In this manner odors will be efficiently controlled within the subsystems and will not (with suitably designed equipment) spread to ambient. No special provisons for odor control will be provided in the toilet/urinal areas.

ATMOSPHERE PURIFICATION AND GAS SUPPLY

All atmosphere purification and composition control functions will be performed in single subsystems as shown in the block diagram of Figure 6-1. The atmosphere conditioning loop will serve as the source of air for the purification circuit. All atmosphere composition monitoring will be effected in this loop.

WASTE COLLECTION

Urinals and toilets will be provided in the hygiene or wet area to accommodate the requirements of the crew. Provisions for collecting trash will be available throughout the space station. Periodically (and as required) the trash will be compacted and stored in a central chamber, which normally will be maintained under vacuum.

Garbage and other wastes that could favor bacteria growth will be sterilized at 230°F before storage with the remainder of the trash. This will require electrical energy, or possibly waste heat from the power supply if available at that temperature level.

Feces will be stored separately in evacuated containers mounted directly under the toilets. The residue from the vapor compression water recovery process also will be stored in a separate tank, which will be changed periodically.

Other items such as used clothing, discarded personal belongings, failed equipment, used filters, etc., will be collected, segregated, processed, and stored in a manner similar to that used for trash and garbage.

WATER RECOVERY AND DISTRIBUTION

Wash water will be recovered by reverse osmosis and recycled. The residue from the reverse osmosis cell will be further processed together with urine by vapor compression/pyrolysis. Centralized subsystems will be used, and fresh water will be distributed to the many use points from the wash and potable water tanks.

Hot and cold water (potable and wash) will be available through cooling and heating at the use points. The thermal management system will provide the heating and cooling capacity required.

MAINTAINABILITY

A factor that represents an important interface between the EC/LSS and the station habitability is maintainability. Not only does the design of a maintainable system reduce the space available for experiment and living (because of generally loose packaging), but maintainability imposes psychological factors on the crew.

A factor of importance here is that a failure should not constitute a panic situation; rather, ample time should be available for repair action. Moreover, for psychological reasons, the occurrence of a failure should not be known to the entire crew; only personnel concerned with system monitoring and maintenance should be alerted.

NOISE CONTROL

The EC/LSS will incorporate a significant number of rotating components (fans, blowers, phase separators, and pumps) which will operate (1) continuously, such as in the atmosphere conditioning and purification loop, and (2) sporadically, as in the waste collection and laundry subsystems. In addition, a number of solenoid valves, reciprocating pumps, and pneumatically operated components will be activated at irregular intervals. This equipment will generate noise that could be propagated throughout the vehicle structure and atmosphere to all areas of the station.

The space station noise problem is not expected to be as acute as on current vehicles, however, because of:

(1) Larger volume of the station

(2) Greater potential for noise reduction offered by the centralized system approach

Reasonable specifications should be drawn considering the adaptation of the crew to a given noise level. Provisions for noise reduction could constitute a sizable weight penalty because of the large number of noise generating components.

Although techniques are available for noise reduction, maintaining noise levels in the range from 40 to 50 db will present a major design problem that might dictate shutdown of some subsystems during sleep periods.

SECTION 7

SLEEP STATION STUDY

7

SLEEP STATION STUDY

DESIGN RATIONALE

Information from research and anecdotal sources (such as naval vessels and antarctic stations) point to the increasing desirability of a combination sleep and privacy area as mission duration increases. Consequently, in considering design recommendations for 6-month missions or longer, this recommendation is unchallenged. The design objective then becomes efficiency of design for this function in terms of volumes, privacy, off-duty activity, personal effects, storage, and other habitability considerations.

To satisfy a need for privacy and personal territory, the concept of personal compartmentization for the sleep station is recommended. Current studies on the Tektite II program have documented once again that crew members have a positive attitude toward private bunk areas. It became an unwritten law on all Tektite II missions (in concordance with vast amounts of historical and anecdotal information) that crew members did not disturb each other when they were in the privacy of their own bunk area.

The individual sleep station (privacy area) provides the crew member with a place to sleep and an opportunity to develop a personal reserve of spatial volume within the confines of the space station environment. Since personal space research has demonstrated that such reserves are an important adjunct to the habitability of the community or public environment, individual sleep station design should allow for the personalization of such volumes according to the desires and tastes of the crew member. To facilitate this personalization of space, the design of these compartments must allow for modification of equipment arrangement, color schemes, partition configuration, lighting levels, and temperatures.

As a personal territory, sleep station design must incorporate more than functional performance. The sleep station must enhance space station habitability because, in addition to sleep, other personal and leisure activities such as viewing the audiovisual monitor, listening to audio presentations, grooming, dressing, reading, one-man games, games involving more than one person, voluntary isolation or privacy, and person-to-person social interaction will take place in the privacy of the sleep station. Since accommodation of more than the sleep function is necessary, the volume-per-man requirements suggested herein exceed those developed in earlier investigations.

Based on studies of groups in isolated environments, it is strongly recommended that personal compartments be provided for each crew member except during periods of crew changeover. It is anticipated that two men will have to occupy each sleeping compartment during periods of overlap when crews are being rotated to and from earth. Provision of a personal compartment will allow the

individual to separate himself from the rest of the crew as desired or necessary. The personal compartment also will provide appropriate demarcation of individual territories. Establishment of personal space boundaries usually occurs with long-term isolation of relatively small groups of men. Demarcations of personal space that are readily recognized and understood by all crew members will minimize misunderstandings and grievances that could occur in the establishment of personal space boundaries.

The general functions of each crew member compartment are to provide for sleeping, separation of each individual from other crew members, relaxation, entertainment, study, grooming, and flexibility to suit individual needs. These functions, which are examined in the paragraphs that follow, must be considered in the compartment design.

Since there is a need for perceptual richness, the contents of the privacy area should be designed such that it can be rearranged during flight. Thus, the internal configuration can be made to conform to some extent to the taste and personality of each crew member. Complexities inherent in designing for human privacy needs will be compounded as cultural differences are encountered from space crews made up of different nationalities.

Information from Tektite confirms the existence of individual differences and preferences for all kinds of things, some of which are as diverse as the location of nonskid tape on the floor. The flexibility to change the interior to suit individual tastes should greatly improve the individual's ability to adapt to the spacecraft.

Sleep should take place in a restraining bag suspended and tensioned at each corner to enhance the "contact feel" of the bag during movements made while sleeping. The bag should consist of three parts: (1) the bag proper, (2) an outer detachable thermal cover, and (3) an inner liner that is detachable and washable. Fasteners of the velcro type could be used for easy and rapid entry and exit from the bag.

The visual isolation functions of the compartment can be met with an appropriate closure to the compartment entrance. Acoustical isolation from noise made by other crew members is more important than general sound level control. Noise control may be achieved by insulation between adjacent compartments, appropriate doorway materials, direction of doorway facings, and partially by low-level acoustical masking (e.g., fan noise).

Leisure activities that may occur in the personal compartment include reading, listening to music, writing, dictating, solitaire and other one-man games, conversations with other crew members, and games that require more than one person.

Grooming that can occur in the personal compartment will be dry shaving (electric), oral hygiene (consumable dentifrice), washing by disposable wipes, and hair and nail maintenance. Shaving with safety razor and whisker retaining cream will be accomplished in the hygiene (wet) area.

Storage space must be provided for crew member clothing and personal effects. A minimum of two sets of outer garments, six sets of underwear, six pairs of socks, two pairs of shoes, and a lightweight jacket will be stored. Also, one of the two space suits provided for each crew member must be stored such that accessibility and donning will not be hindered in case of emergency. The compartment should be fitted with a suit loop fitting to the environmental control system (ECS) and sufficient umbilical to allow fitting-to-fitting progression from the compartment to the pack storage area.

Multi-source lighting should be provided for reading, table activities, and grooming. Color temperatures of direct and indirect light sources should be varied on a daily schedule to promote the maintenance of normal circadian cycles.

An audiovisual device in the form of a cathode ray tube (CRT) and keyboard is recommended for off-duty and operational use. Off-duty uses would include study, recreation, and private communication with facilities on earth, while operational uses would include display of maintenance instructions, emergency alarm instructions, and mission related communications. All audiovisual information will be presented by this one display center. The use of a keyboard vastly increases computational and data access capabilities. The use of a device of this type is supported by data from the Tektite program, in which the use of a two-way closed-circuit TV system eliminated hostility that normally develops between crew members in the habitat and those topside. People saw other people in action both during leisure time and during work, and this visual contact developed a better understanding of the exigencies of the people above and below the water surface. Some crews on Tektite enjoyed the two-way TV so much that they spent considerable leisure time just watching it. For this reason, some requested that it be installed in the crew's quarters instead of on the bridge. The data from Tektite indicate that attitude toward "topside" is a particularly important factor in adjustment to an isolated habitat. Development of positive attitudes toward ground-based personnel will be related to more positive habitability ratings of the space station and more positive moods during the day. Thus, it appears that facilities offering informal communication with space station people, particularly family and friends, can be instrumental in fostering good adjustments to an isolated habitat.

VOLUME CONSIDERATIONS

The volume requirements for the privacy area are dependent upon that volume necessary to don the space suit, store personal belongings, and provide for sleeping. The requirement for personal space and/or personal territory is satisfied by the demarcation of the personal compartment. Many arrangements have been evaluated for both one- and two-man privacy compartments, and possible layouts of such configurations are shown in figs. 7-1 through 7-6. For a 180-day mission, the recommended minimum volume for a one-man privacy compartment is 250 cu ft (fig. 7-5). This configuration provides a free floor area of 21 sq ft

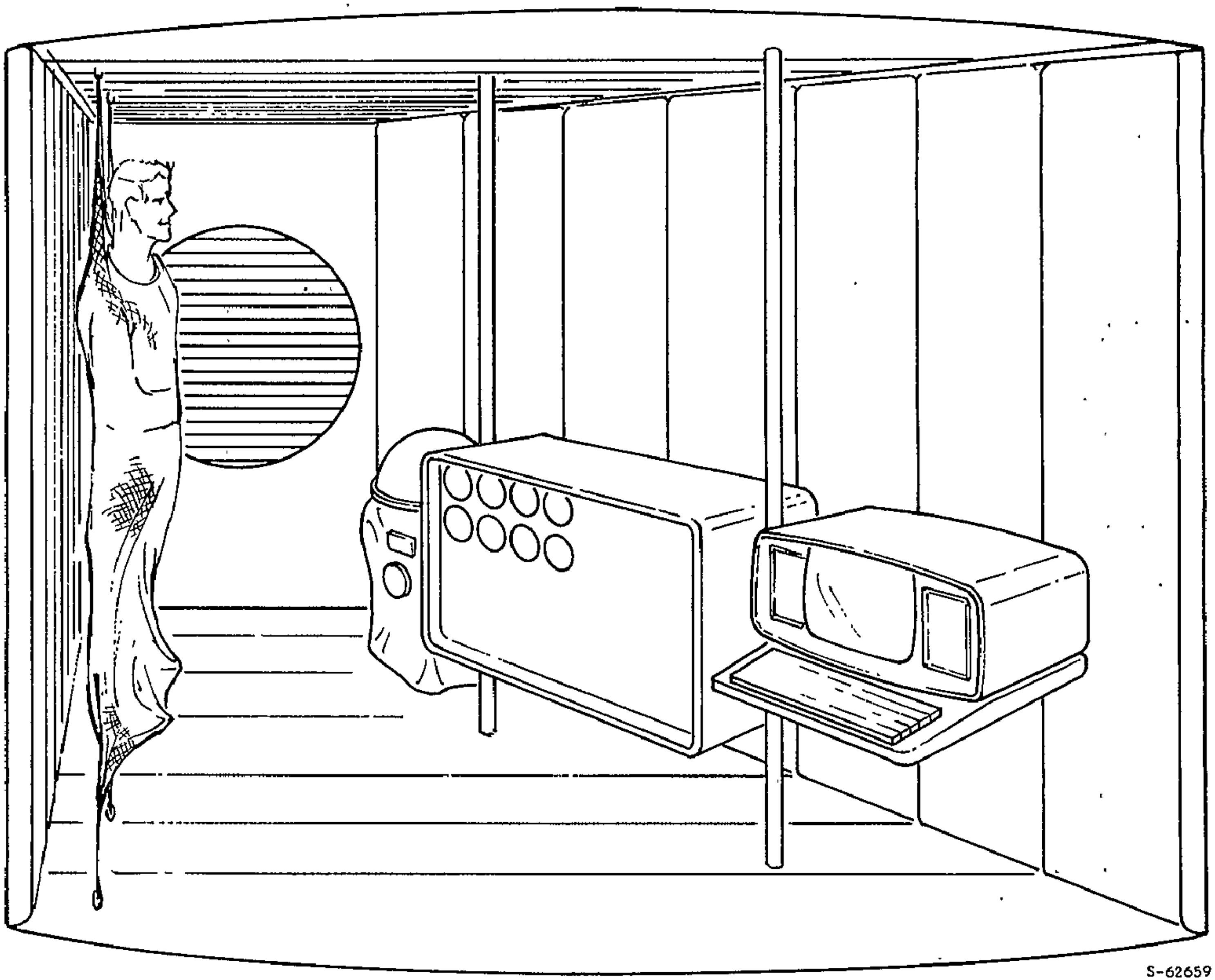

Figure 7-1. Typical Crew Member Privacy Area

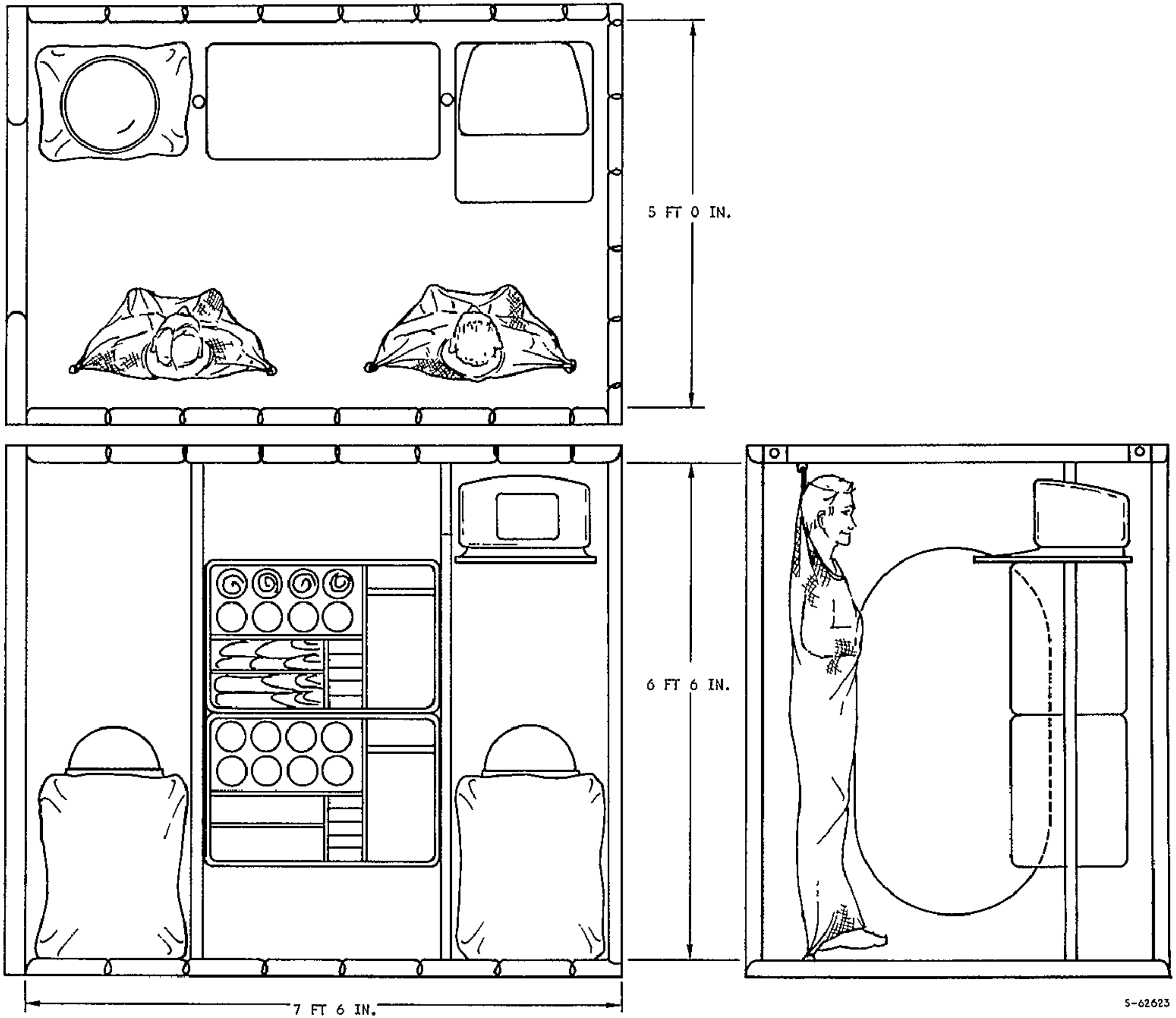

Figure 7-2. Individual Rest Area With Two Crewmen

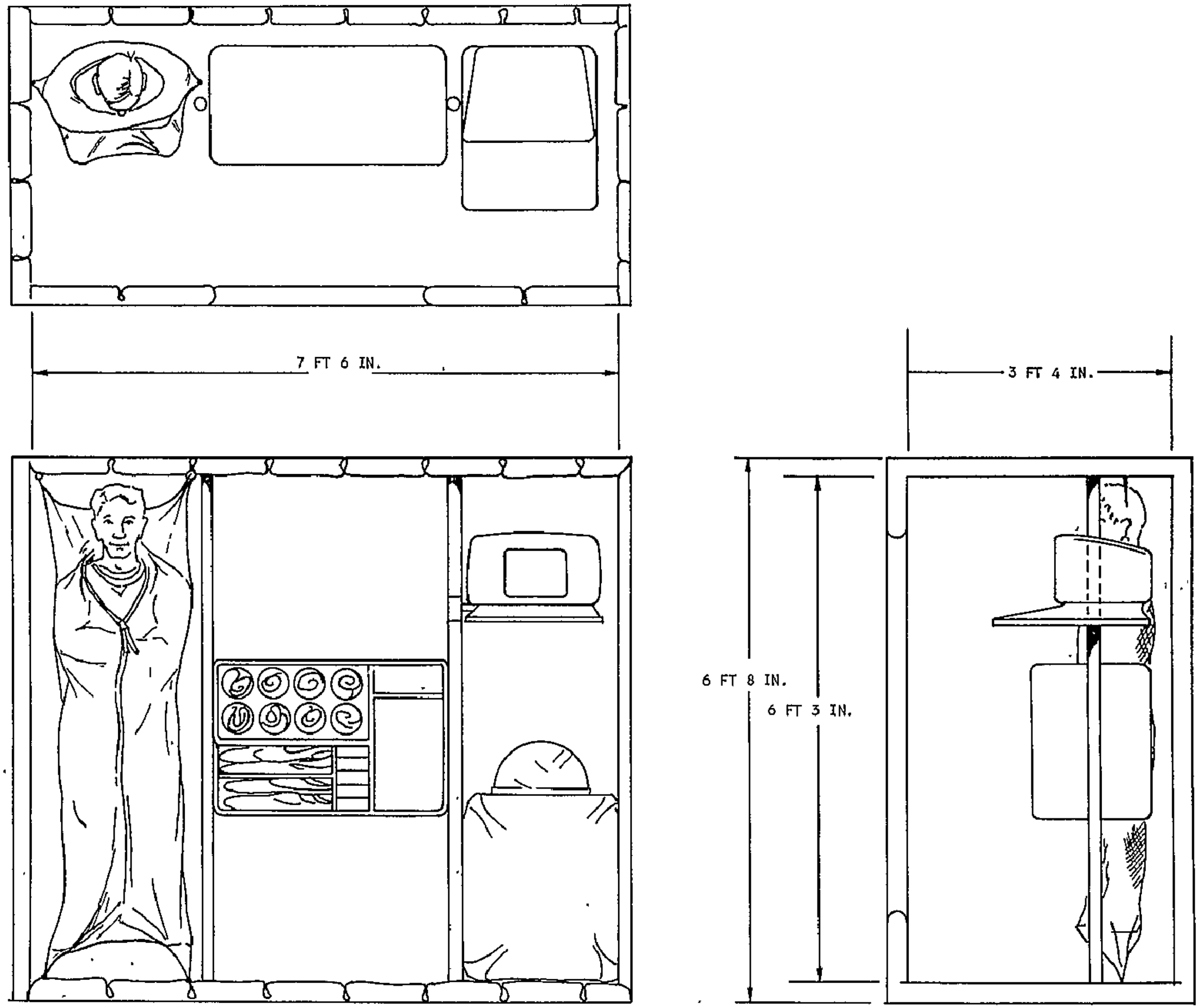

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Figure 7-3. Minimum Individual Rest Area: 156 Cu Ft

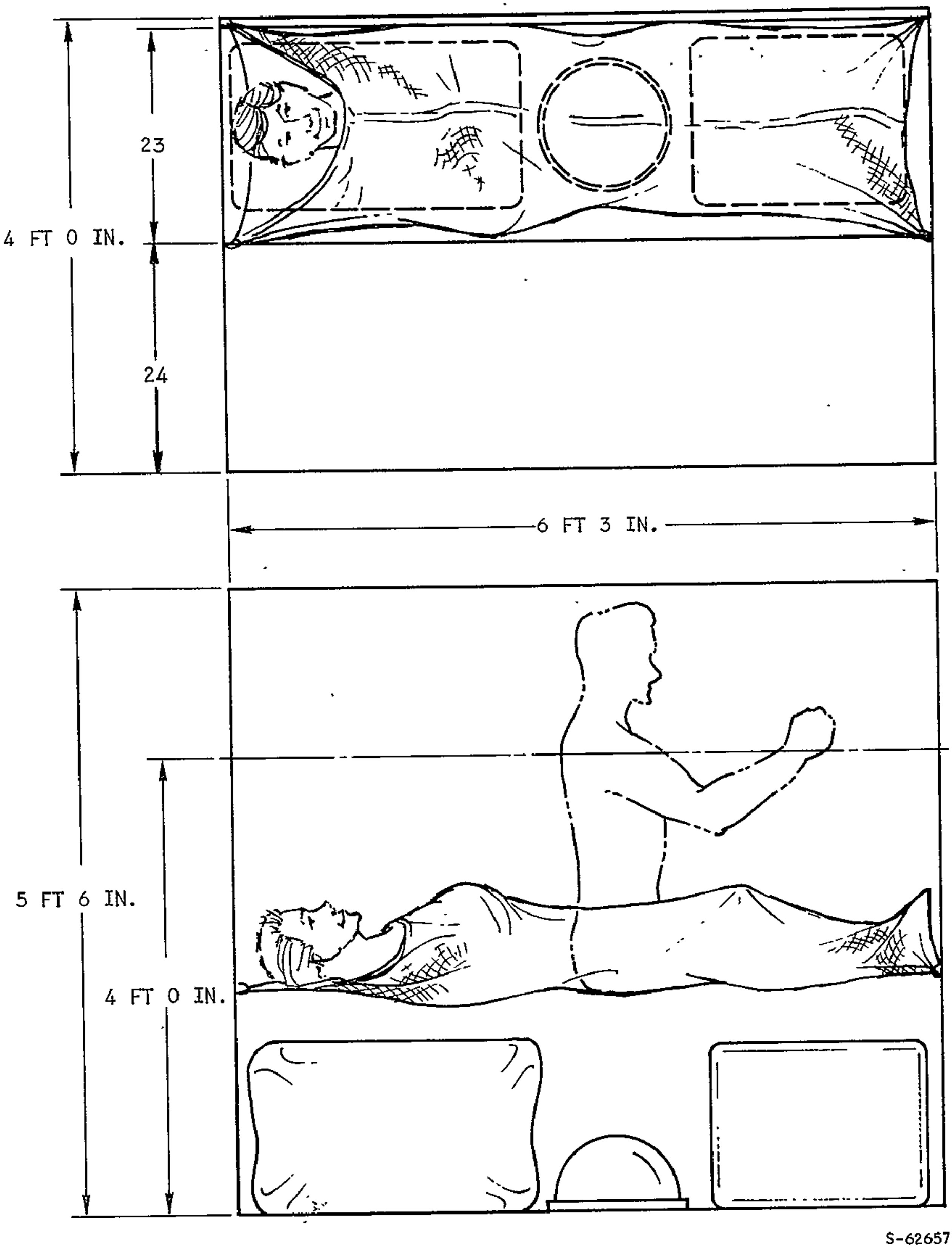


Figure 7-4. Minimum Individual Rest Area: 137.5 Cu Ft

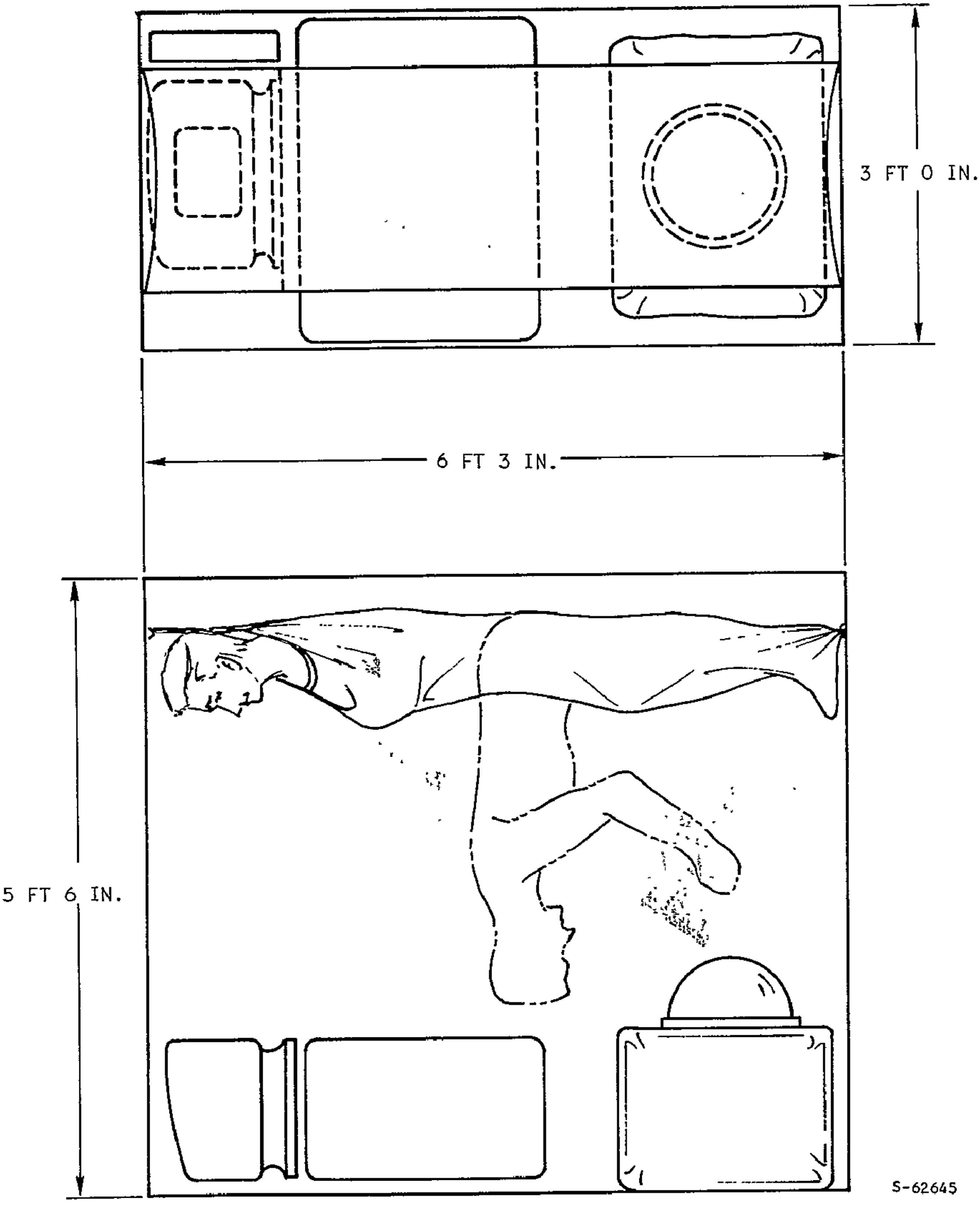


Figure 7-5. Minimum Individual Rest Area: 103 Cu Ft

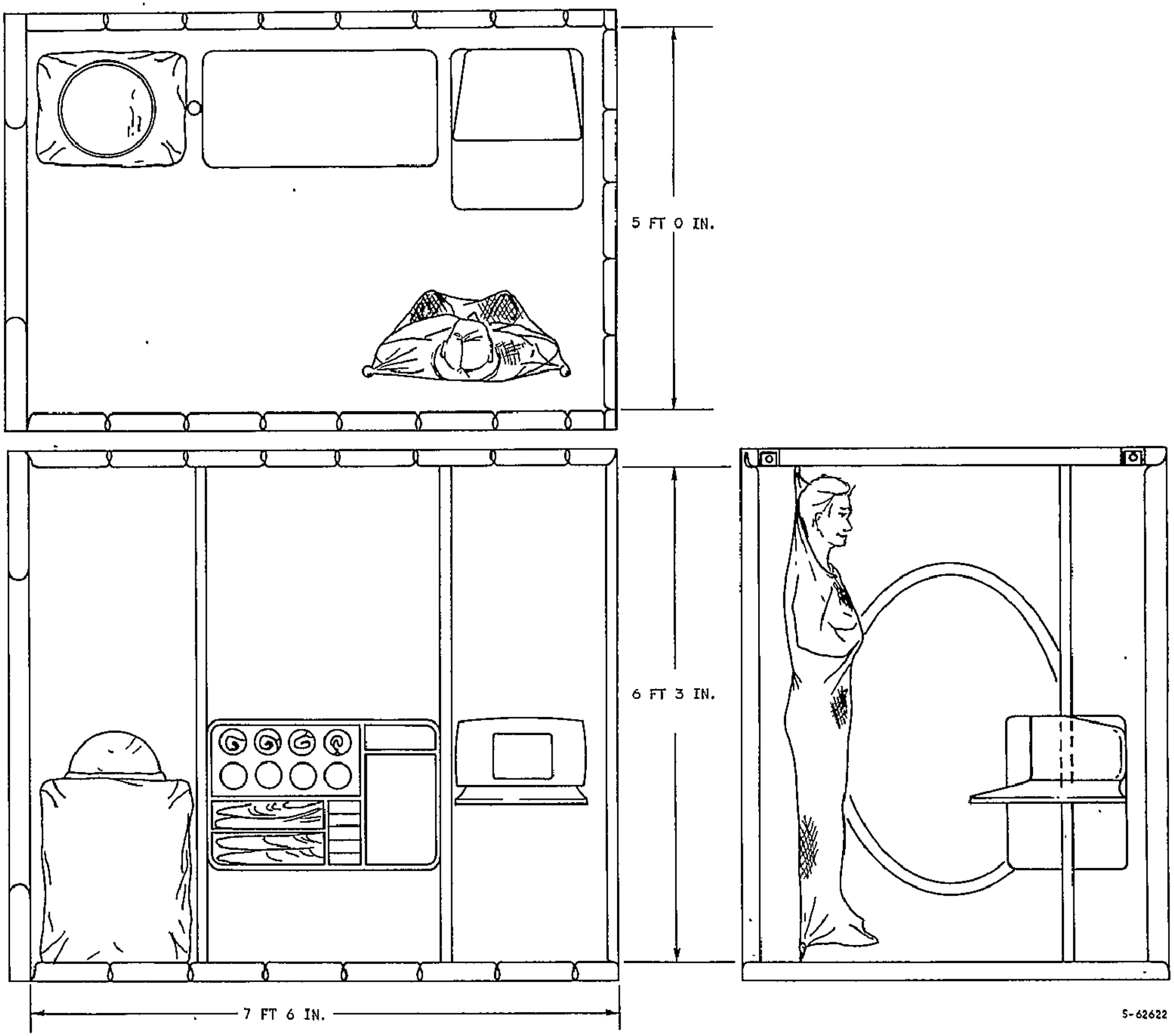


Figure 7-6. Individual Rest Area: 225 Cu Ft

and a free volume of approximately 126 cu ft for space suit donning. The volume required for donning the space suit may vary slightly depending upon suit design. The detailed sleep compartment volume requirements are listed in table 7-1.

TABLE 7-1

VOLUME REQUIREMENTS

Volume required for:	Volume required, cu ft
Space suit donning and doffing	8
Bunk	8
Storage of space suit	9
Storage of personal belongings	9
Desk viewmaster	6
Body volume	23
Free volume*	117

*Free volume is defined as the volume necessary to achieve the subjective evaluation of "a comfortable compartment." This also includes inaccessible volumes of the cabin.

To determine the additional volume required to provide individual privacy areas, a volume versus crew size matrix was developed. Specific considerations must be incorporated into the volume rationale when more than one crew member inhabits a sleep area. The matrix shown in Table 7-2 indicates the recommended minimum volume for multisize crews under two sets of conditions--(1) each man occupying a separate sleep area and (2) all men occupying the same sleep area. The matrix includes the volume necessary for each specific requirement for both conditions 1 and 2. Within each box, the number above the diagonal line is the total volume necessary for all crew members sleeping in individual areas; the number below the diagonal line represents the volume required by all crew members sleeping in one area. This is depicted below.

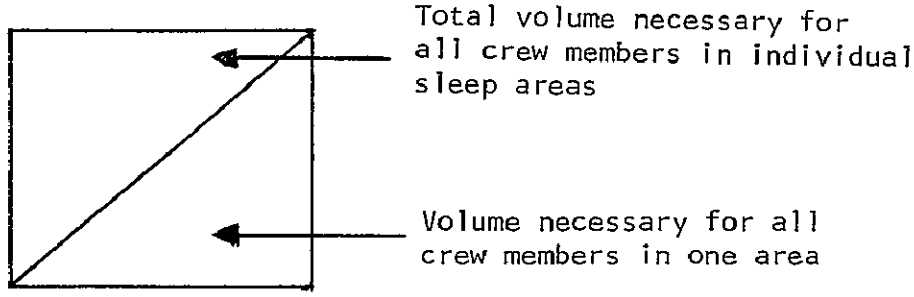


TABLE 7-2

VOLUME VS CREW SIZE MATRIX

Volume Required by	Volume Required, cu ft per crew size											
	1 man	2 men	3 men	4 men	5 men	6 men	7 men	8 men	9 men	10 men	11 men	12 men
Bunk	8 / 8	16 / 16	24 / 24	32 / 32	40 / 40	48 / 48	56 / 56	64 / 64	72 / 72	80 / 80	88 / 88	96 / 96
Personal Belongings	9 / 9	18 / 18	27 / 27	36 / 36	45 / 45	54 / 54	63 / 63	72 / 72	81 / 81	90 / 90	99 / 99	108 / 108
Audiovisual	6 / 6	12 / 12	18 / 12	24 / 12	30 / 12	36 / 12	42 / 18	48 / 18	54 / 18	60 / 24	66 / 24	72 / 24
Body Space	23 / 23	46 / 46	69 / 69	92 / 92	115 / 115	138 / 138	161 / 161	184 / 184	207 / 207	230 / 230	253 / 253	276 / 276
Suit Storage	9 / 9	18 / 18	27 / 27	36 / 36	45 / 45	54 / 54	63 / 63	72 / 72	81 / 81	90 / 90	99 / 99	108 / 108
Suit Donning	78 / 78	156 / 156	234 / 234	312 / 312	390 / 390	468 / 468	546 / 546	624 / 624	702 / 702	780 / 780	858 / 858	936 / 936
Free Volume	117 / 117	234 / 62	351 / 150	468 / 200	585 / 250	702 / 300	819 / 350	936 / 400	1053 / 450	1170 / 500	1257 / 550	1404 / 600
Total	250 / 250	500 / 328	750 / 543	1000 / 720	1250 / 897	1500 / 1074	1750 / 1257	2000 / 1434	2250 / 1611	2500 / 1794	2750 / 1971	3000 / 2160

In preparing the volume versus crew size matrix, the following rationale provided guidelines:

(1) Bunks for multi-man compartments can be located arbitrarily as long as the integrity of each individual personal space and territory is maintained and the bunk placement does not create inaccessible areas.

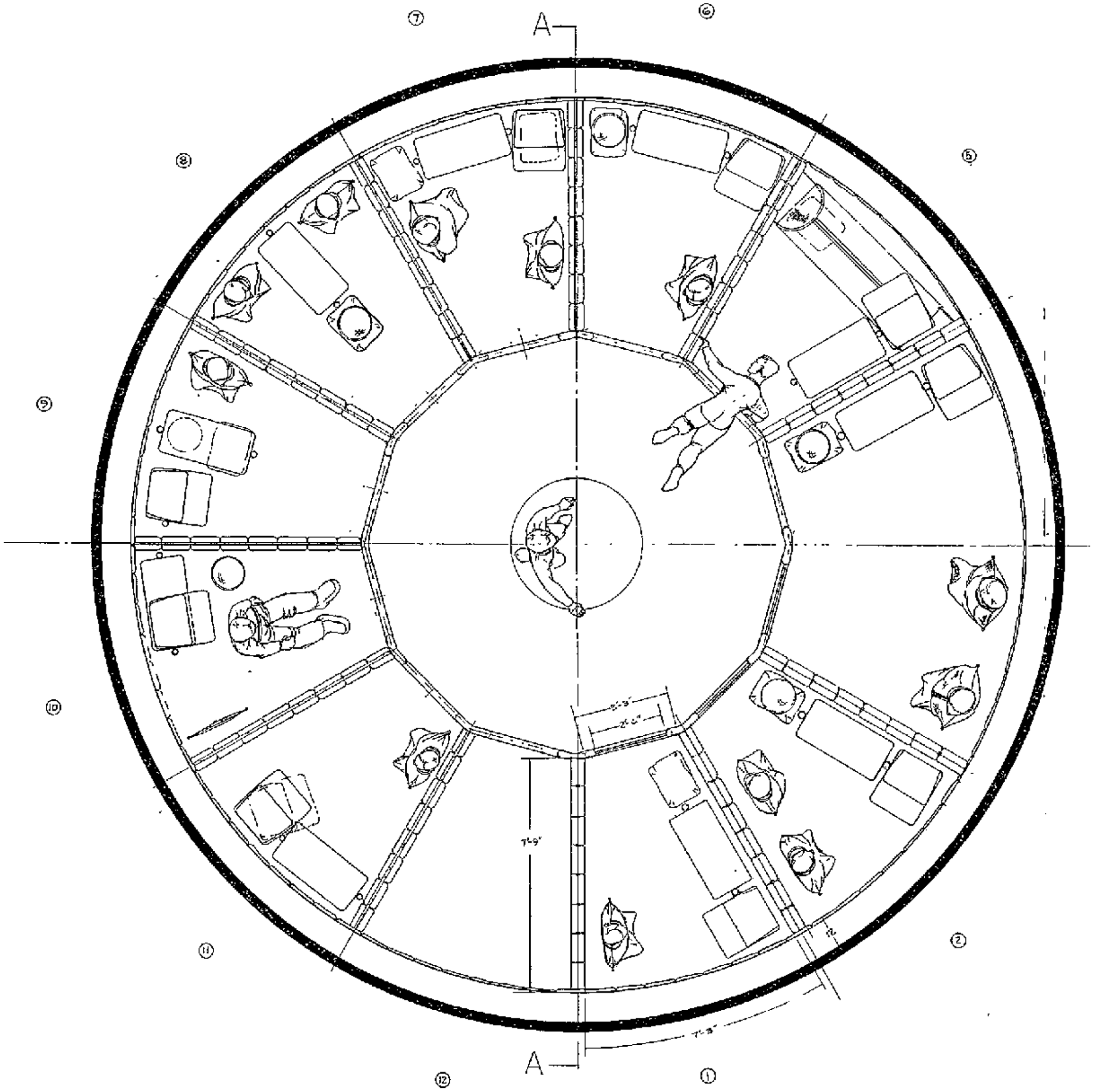
(2) In multiman quarters, an audiovisual device will not be required for every member. Space can be saved by sharing two displays for two through six men; three would be supplied for seven through nine men; and four would be supplied for ten through twelve men. The numbers recommended should be confirmed by additional research.

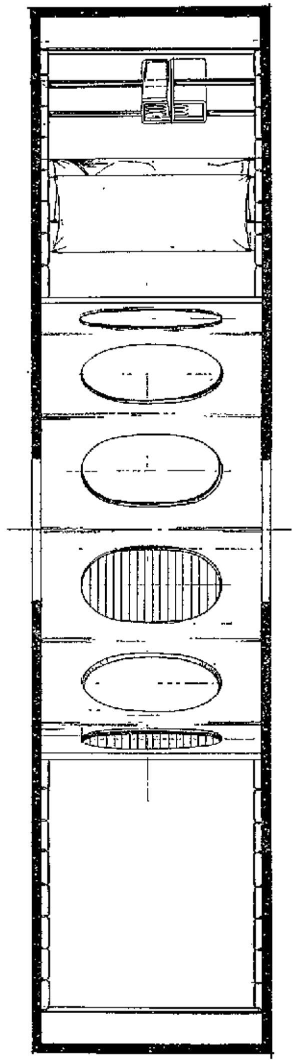
(3) The free volume assessment includes unusable volume of the compartment plus that volume necessary to allow traffic flow and psychological considerations for spaciousness. Specific volume requirements for spaciousness considerations have not been demonstrated in actual space environment conditions; therefore, a linear volumetric increase of 50 cu ft per additional man above two has been included to account for the unusable volume. To obtain the free volume required for a two-man area, the bunk, personal belongings, audiovisual device, body space, and suit storage for the second man can be installed into the free volume of the one-man compartment without affecting traffic flow.

SLEEPING COMPARTMENT CONFIGURATIONS

Designing all components that will be in the sleeping area to a modular base will provide flexibility for rearranging the interior. Typical furnishing arrangements in the sleep area of a 33-ft-dia spacecraft are shown in fig. 7-7. A 1-ft clearway has been left around the circumference for access to plumbing, wiring, and components.

Bay No. 1 contains a typical basic privacy area arrangement for one man. Included is a sleeping restraint, stowage compartment, EVA suit and helmet, and audiovisual device. Bay No. 2 shows the basic arrangement with an additional crew member and his gear during crew changeover. During crew changeover, 24 men will be aboard the spacecraft; a second sleeping restraint is suspended, and the stowage compartment stacked. With this arrangement, there is room in the compartment for only one man to rapidly don the EVA suit in an emergency. For bays 3 and 4, space for both men to rapidly don their suits is available if an inflatable wall is removed and equipment stacked as shown. This additional flexibility permits the buddy system to be followed for those members who prefer companionship to privacy. Since wall removal is an option with an inflatable wall, privacy is retained for those desiring to maintain it. Flexibility to change the walls provides an efficient use of space for a variety of activities, i.e., sick bay, operating room, etc. A horizontal sleeping restraint is shown in bay 5 with an audiovisual viewer directed toward the crewman's resting position. All equipment is arranged along the right wall. In bay 6, all equipment is arranged along the far wall, and the sleeping restraint is along the right wall.





SECTION A-A

Figure 7-7. Living Quarters

FOLDOUT FRAME 1

FOLDOUT FRAME 2

In bay 7, two men are shown in the basic arrangement described for bay 6. Equipment is stacked modularly along the far wall. In bay 8, two men are shown in one cubicle with the two stowage compartments stacked as dividers for privacy. This arrangement does not permit the inclusion of the audiovisual viewer but does provide suit donning space. Bays 10, 11, and 12 show different furnishing arrangements for single occupancy of the privacy area, and space is allowed for donning the EVA suit.

The sleep compartment interior should be entirely soft with a minimum of hard protrusions (fig. 7-8a). Hard protrusions would be hazardous to crew free-flight (zero-g) movement, and this would greatly impede mobility through the spacecraft. Unobstructed flyways are highly desirable for freedom of mobility through the spacecraft. Padding with built-in hand grips (fig. 7-8b) should cover the floor and ceiling. A 6-ft 6-in. ceiling height would enable the crewman to reach and make contact with the ceiling. Mobility also will be effected through grips on the walls and floor.

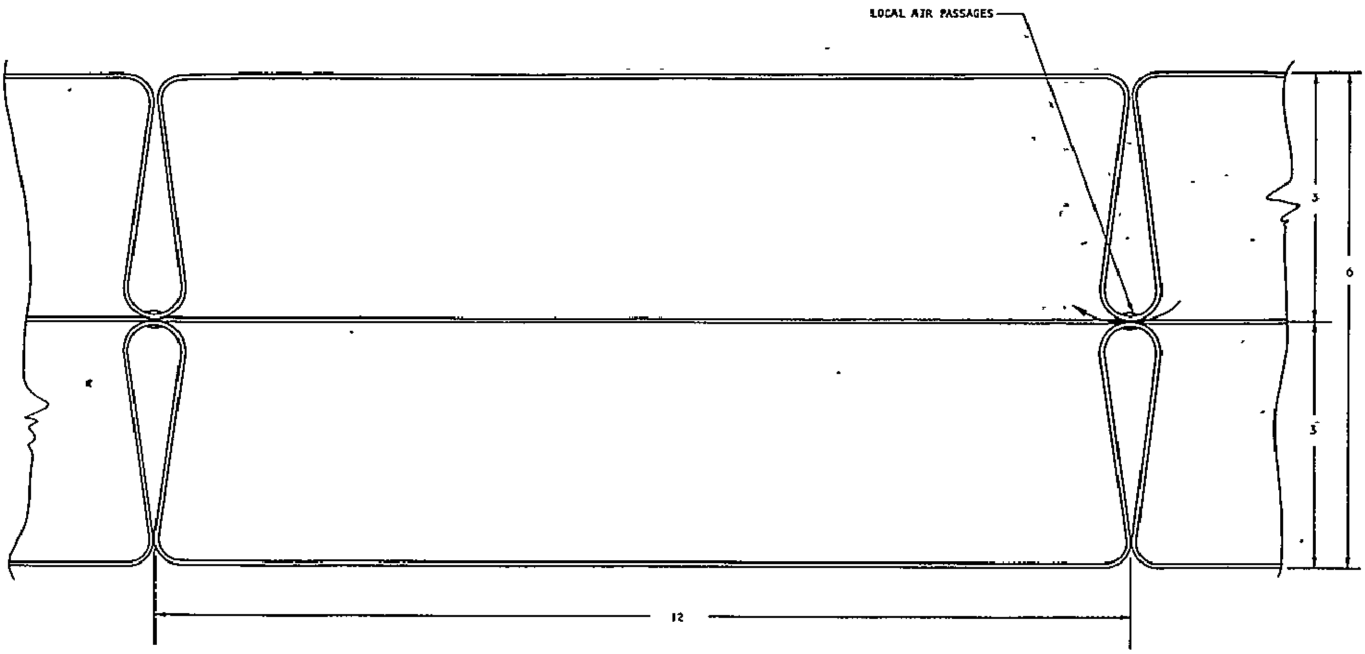
Flexibility to change the color interior scheme can be achieved through lighting, rearranging panels,or changing wall hangings. Pictures, photographs, and other items of familiar scenes or faces can be changed and rearranged to lessen habituation. The ceiling and floor should be easily identified during free-flight to reduce maneuvers and provide orientation.

All floors will be on the same plane to provide a basis for orientation for the entire crew. All equipment will be related to this plane to establish a common reference that is unchanging from familiar earth orientation. Previous studies have shown that there is a need for a common reference plane to prevent crew disorientation.

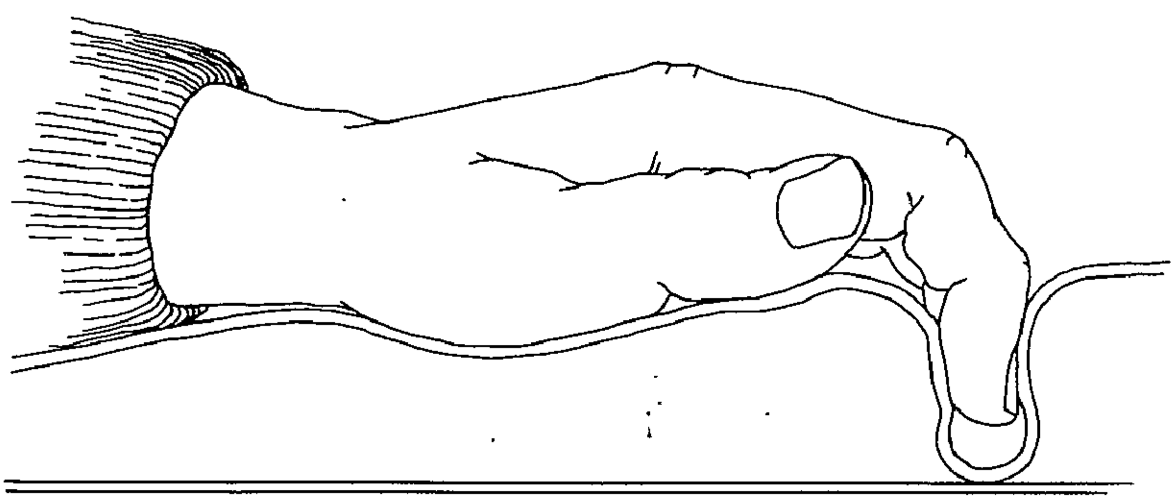
Texture and color also will be used to aid identification of the floor for touchdown. The floor color should be darker in value and coarser in texture than the ceiling.

LIGHTING

Ambient lighting should be provided by recessed fixtures to conceal the light source. Colored filters that can be changed to suit the occupant should be used to provide local colors. Lighting is discussed in more detail in Section 5 of this report.



a. Inflatable Wall for Privacy, Acoustical Control, and Mobility



b. Hand Depression for Mobility

Figure 7-8. Sleep Area Wall Construction

RESTRAINTS

Rest Restraints

A lightweight restraining device (see fig. 7-10) that prevents the crewman from drifting about the interior while sleeping should be loose and provide freedom for turning and tossing. Uncomfortable restraining straps or other devices should not be used. A zipper or velcro should be provided down the restraint front to allow quick and easy entering and exiting in case of emergency. A lightweight liner can be used at the crew member's option for additional warmth; the interior temperature of the spacecraft will be set for a shirtsleeve environment. Ventilation will occur through the loose weave of the restraining tube, and the elastic shock cord will keep the entire tube taut to provide a comfortable sleeping restraint.

Seating Restraint

Conventional seating used in earth gravity environments is not needed in the zero-g environment. Instead, restraints and work positioning devices will be required. Thus, load-carrying seats for positioning the body for various work and rest activities will not be required. Restraining devices will be necessary to present the astronaut to the work station and to provide a reaction base for work activities. Restraints must:

(1) Stabilize the operator at the work station

(2) Provide torque cancelling

(3) Attach and release easily and rapidly

(4) Provide adjustments for individual differences

(5) Be comfortable for long-duration tasks

Seating restraints are discussed in more detail in Section 9.

PERSONAL EQUIPMENT STORAGE

Personal equipment to be taken aboard and stowed in the sleep area, as shown in fig. 7-9, can be grouped into personal clothing, toilet articles, and recreation items. Clothing items (fig. 7-10) that will be stowed in the sleep compartment include:

(1) Two outer garments

(2) Six sets of undergarments

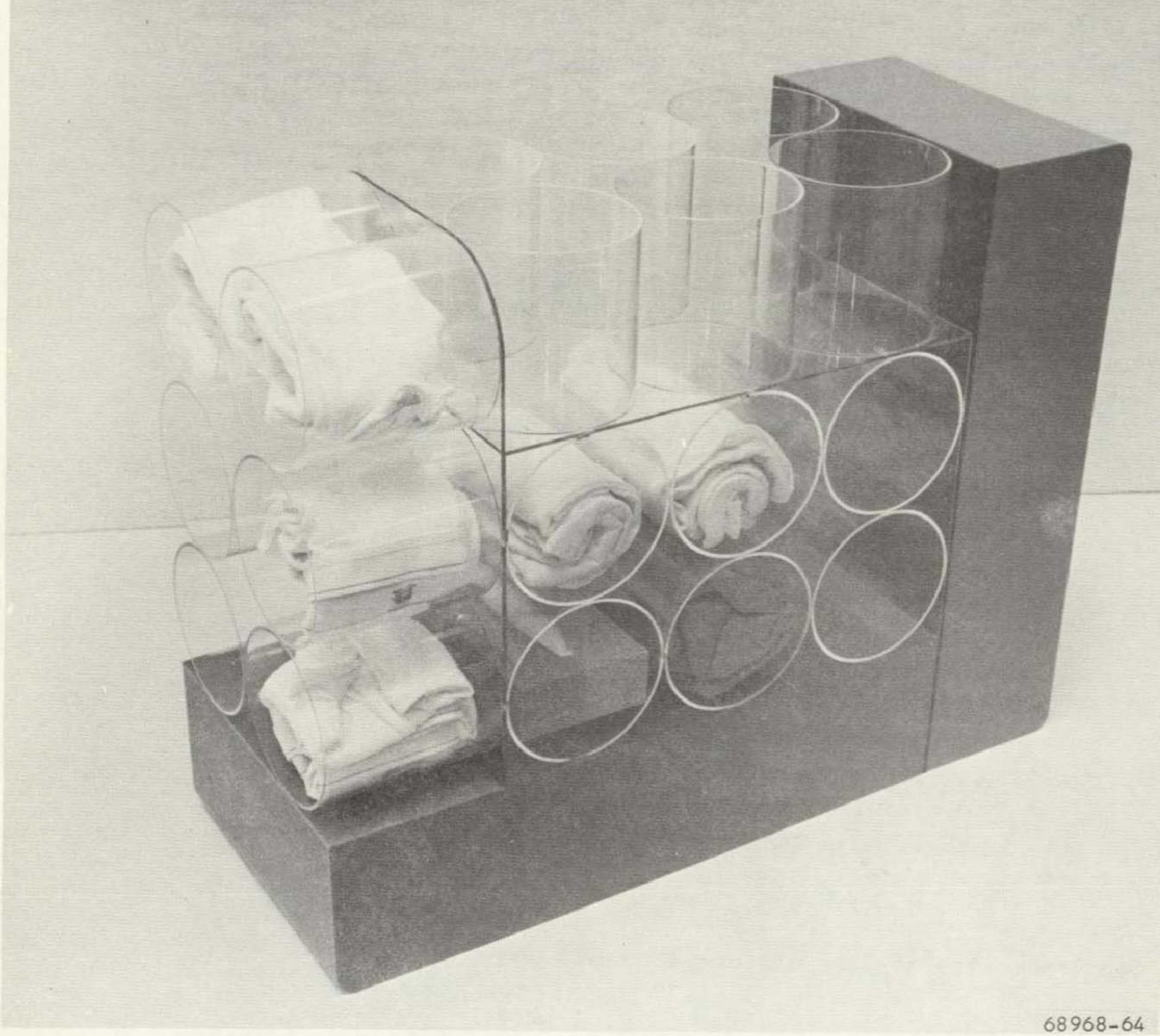
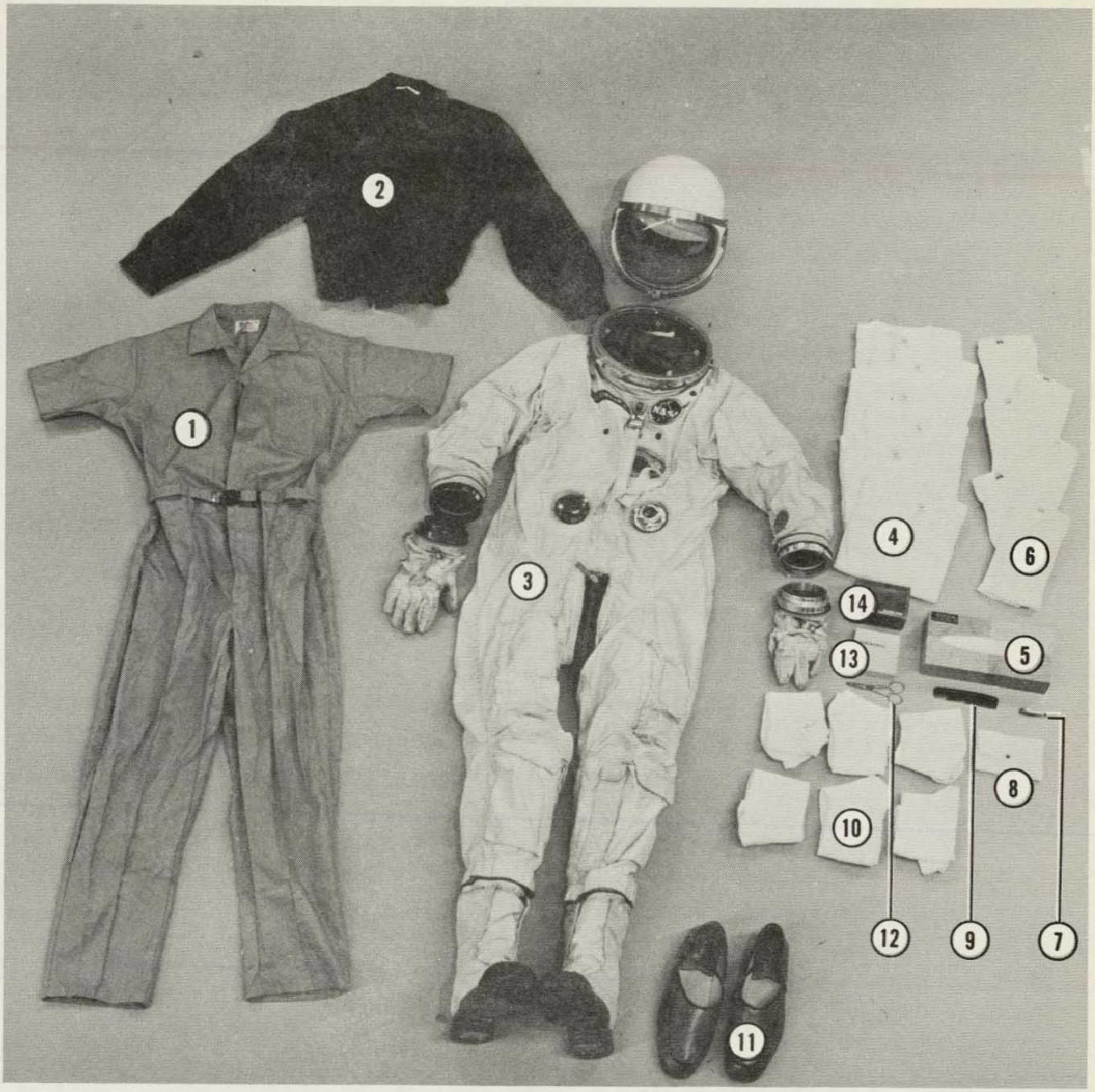


Figure 7-9. Personal Clothing Storage Concept



1. OUTER GARMENT (2)
2. JACKET
3. PRESSURE SUIT
4. UNDERSHIRTS (6)
5. WIPES
6. SHORTS (6)
7. NAIL CLIPPER AND FILE
8. MENDING KIT
9. COMB
10. SOCKS (6)
11. SOFT SHOES
12. BLUNT SCISSORS
13. DENTIFRICE
14. RAZOR

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Figure 7-10. Personal Equipment

(3) Six pairs of socks; two pairs of shoes (with mending kit)

(4) Lightweight jacket

(5) One EVA pressure suit per man (emergency)

Toilet articles that will be stowed in the sleep compartment are:

(1) Electric razor

(2) Comb

(3) Consumable dentifrice

(4) Nail clipper and file

(5) Scissors

(6) Wipes (Kleenex)

Recreation items that will be stowed in the sleep compartment are:

(1) Preselected music (tapes)

(2) Preselected education courses

(3) Writing and sketching material

(4) One-man or small group games (cards, chess, checkers, dominoes, etc.). Large group games will be furnished from spacecraft storage.

(5) Pictures and photographs

An audiovisual device (including a teaching machine) also will be stowed in the sleep compartment for reading, personal development, and personal communication.

MOCKUP EVALUATION

A soft mockup was fabricated and used to evaluate the space planned for the sleep area. Foam board was fastened over plywood stringers for rigidity. Emphasis was placed on defining the space, color, and texture as accurately as possible for minimum cost. Cost performance was also the basis for mockup of the individual equipment items. Items were built of hard materials and finished only where they were important to the problem solution. Mockups of two cubicles were made using minimum volume concepts from other sources. Both of these concepts were later discarded as unsatisfactory because insufficient volume was provided for the required use.

The first mockup is shown in fig. 7-11. The 103.25-cu ft volume contains all of the equipment including audiovisual device. Disadvantages to this concept are the lack of volume for crew sharing during turnover and for receiving visitors. Also, the height between the floor and ceiling is not sufficient for taller crew members to stand. An additional disadvantage of this concept is the lack of volume for donning the suit in an emergency.

The second mockup is shown in fig. 7-12. In the 137.5-cu ft volume, everything is stowed beneath the bunk except the audiovisual device, which is not included. Subjects exposed to the mockup version of these minimum cubicles consistently reported the subjective feeling that these cubicles were too small to be lived in for extended periods of time.

Larger cubicles, one of which is shown in figs. 7-13 and 7-14, were designed, mocked up as rectangles, and then fitted into a cylindrical form. Walls were oriented radially to make the best use of space in a circular form because rectangular forms placed in a cylinder result in a great loss of volume, and/or create small irregular spaces that are difficult to use. The larger cubicles allow for personal space, define personal territory, and result in a nice spatial feel while providing privacy for the inhabitant.

Visual change can be brought about by varying the lighting (fig. 7-15), changing the colors, rearranging the panels, and rearranging the furnishings. In addition the wall can be moved to provide a completely new environment. All of these devices provide flexibility to reduce habituation and eliminate boredom.

Soft surfaces of the walls, floor, and ceiling were formed to include hand and foot traction for zero-g maneuverability (fig. 7-16). The ceiling (fig. 7-17) was covered with a packing material consisting of inflated hemispheres formed from two sheets of plastic. The floor covering, shown in fig. 7-18A, consisted of foam in the shape of conical fingers. Although this arrangement seemed to work well, it may be better to reverse the floor and ceiling materials; putting the foam with conical protrusions on the ceiling might provide better mobility because it is easy to insert the fingers of the hand between the cones. The hemispheres would provide soft cushioning for the feet and shapes for the toes to grip.

These materials were selected to provide a soft interior for collision protection while providing integral mobility grips. An alternate arrangement for mobility is the netting that is stretched taught and stands away from the padded surface 1-1/2 in. (fig. 7-19). This arrangement provides good finger grips, but during free flight may also snag fingers and items such as glasses.

Alternate foam floor material, shaped as shown in fig. 7-20, with cylindrical holes will provide the necessary traction and collision protection while furnishing openings for the modular furniture sockets that would permit the units to be moved to different locations.

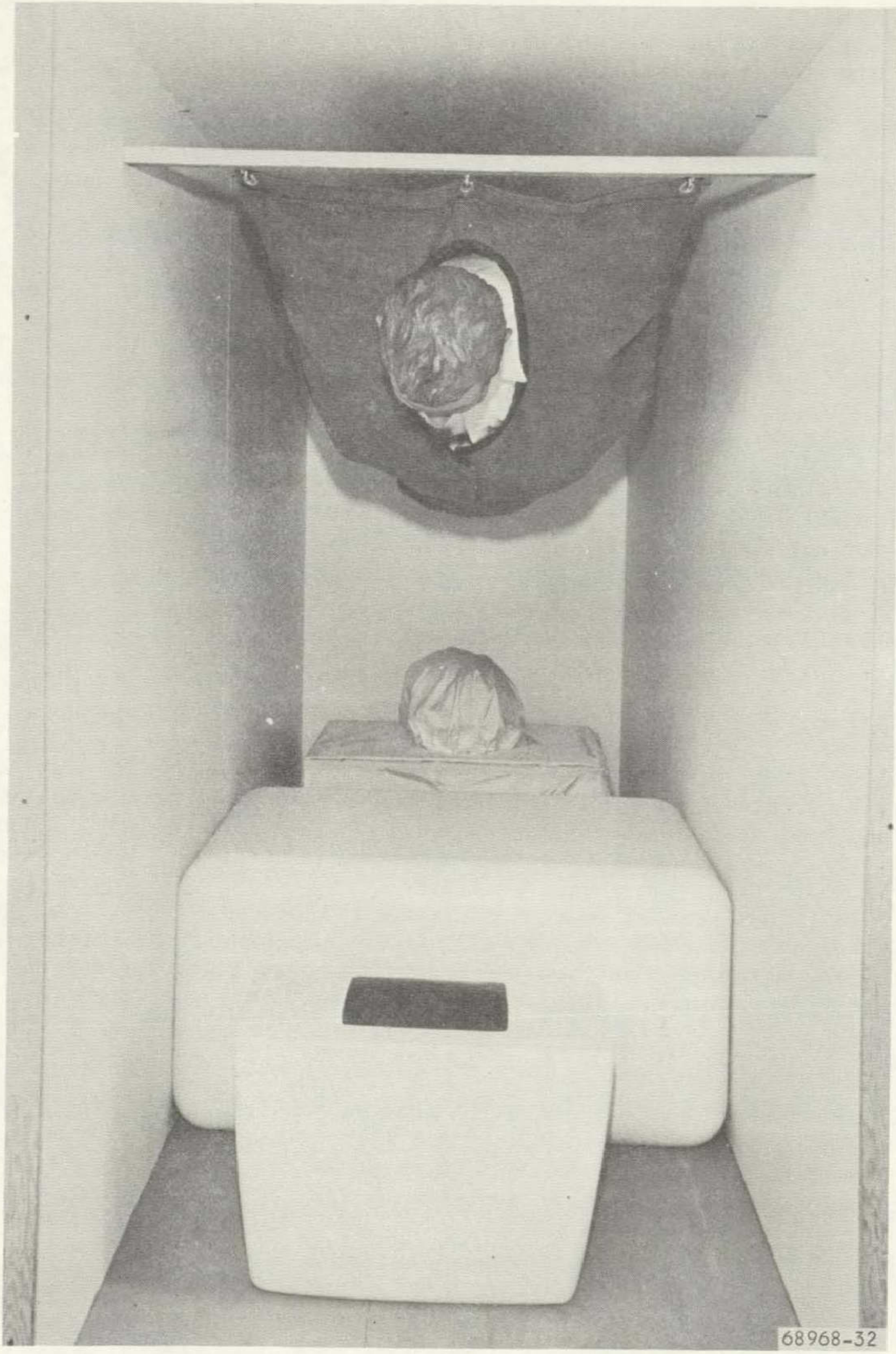

Figure 7-11. Minimum Rest Area: 103-1/4 Cu Ft
(36 ft by 75 ft by 66 ft)

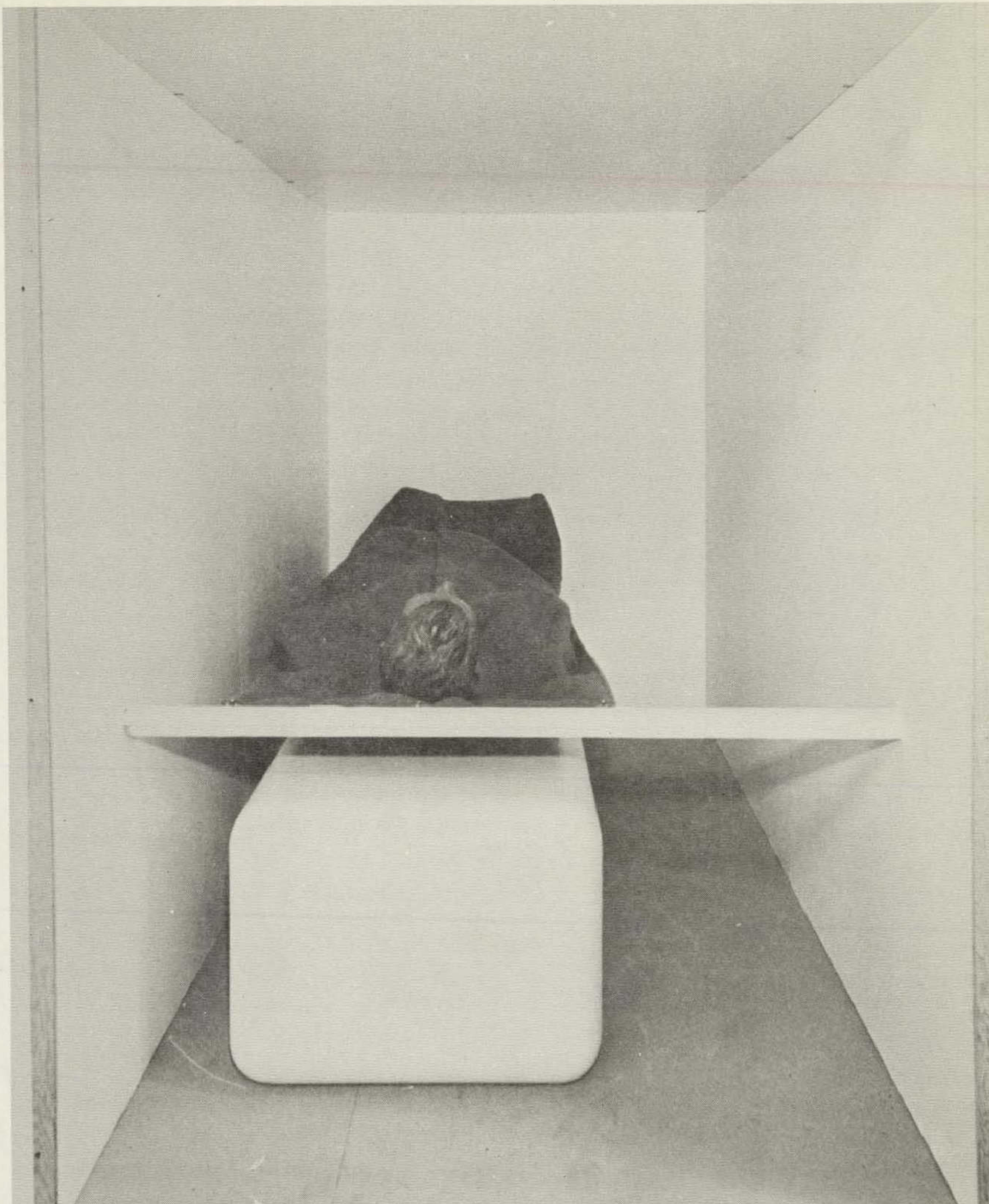

Figure 7-12. Minimum Rest Area B: 137.5 Cu Ft
(48 ft by 75 ft by 66 ft)

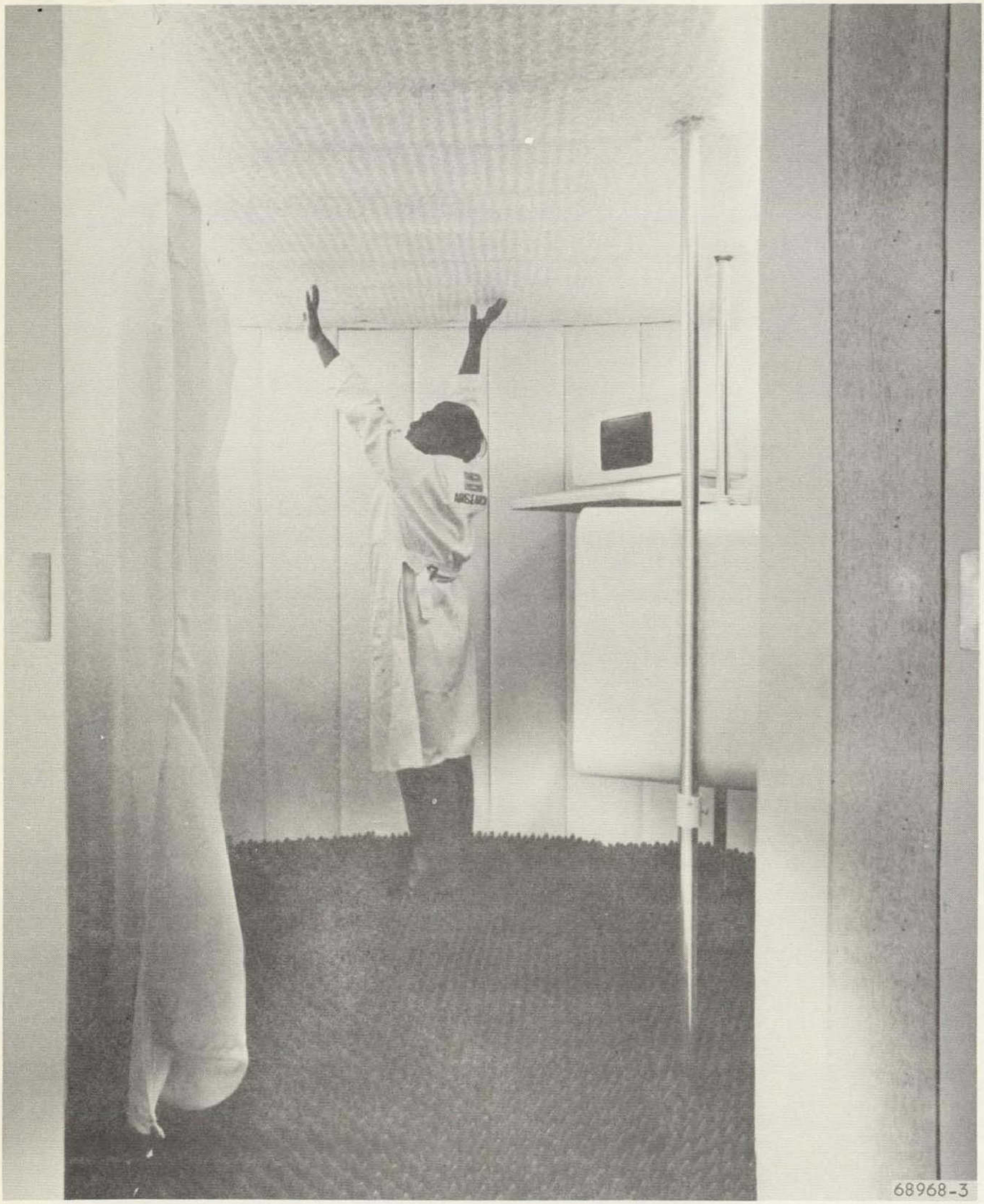

Figure 7-13. Mockup of Minimum Rest Area

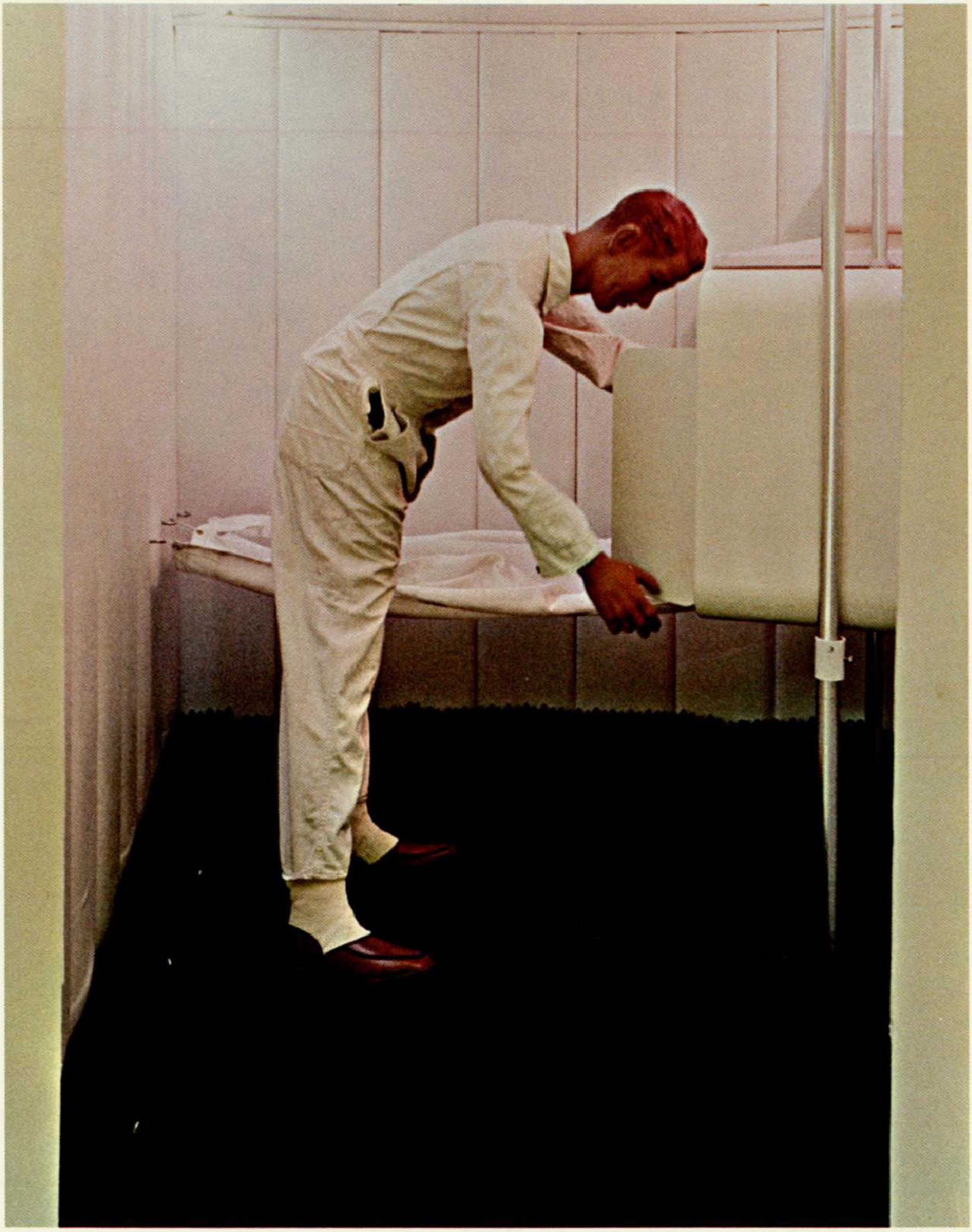

Figure 7-14. Maneuvering Space After Restraint Attached to Walls and Parallel with Floor

Figure 7-15. Varied Lighting for Visual Change

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Figure 7-16. Soft Surfaces for Zero-G Maneuverability

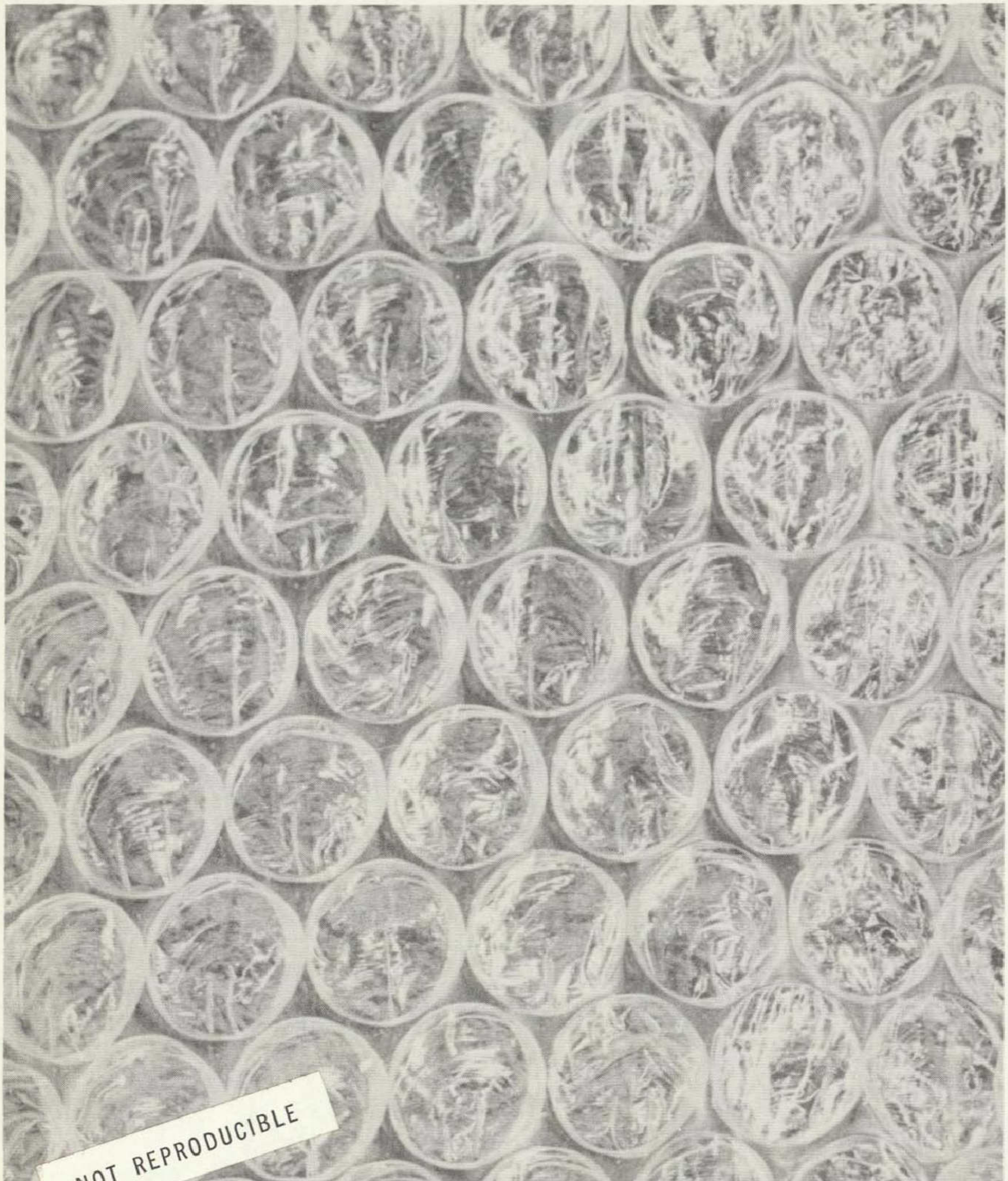
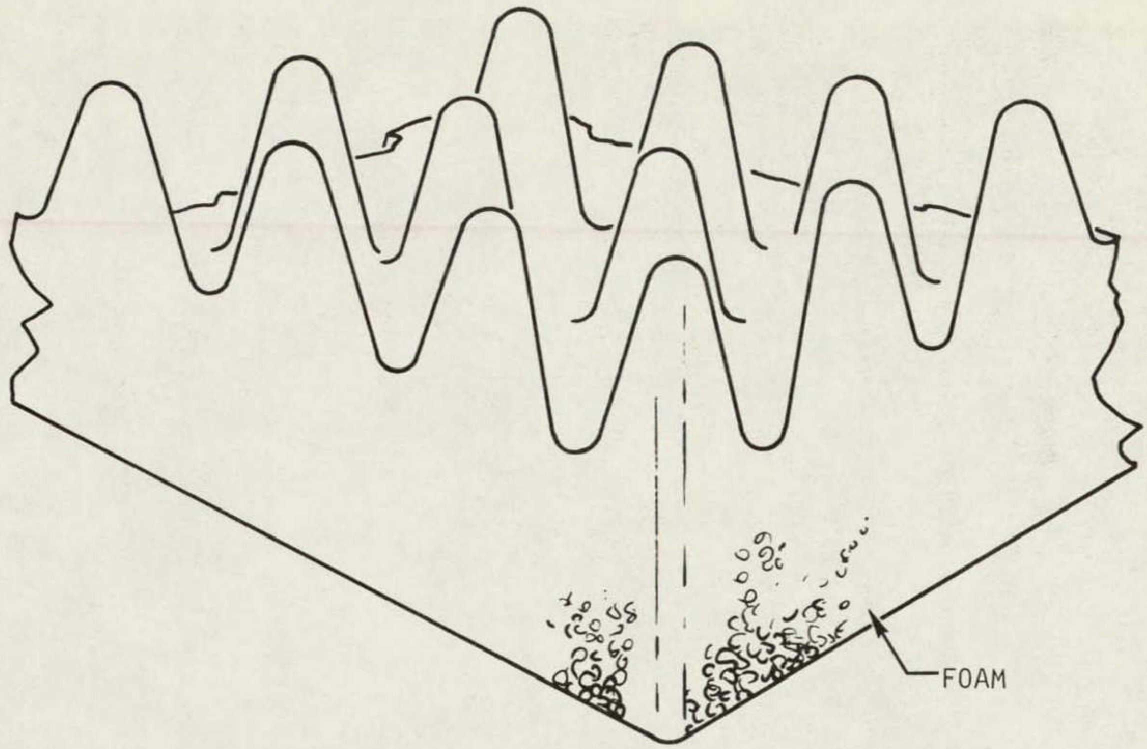
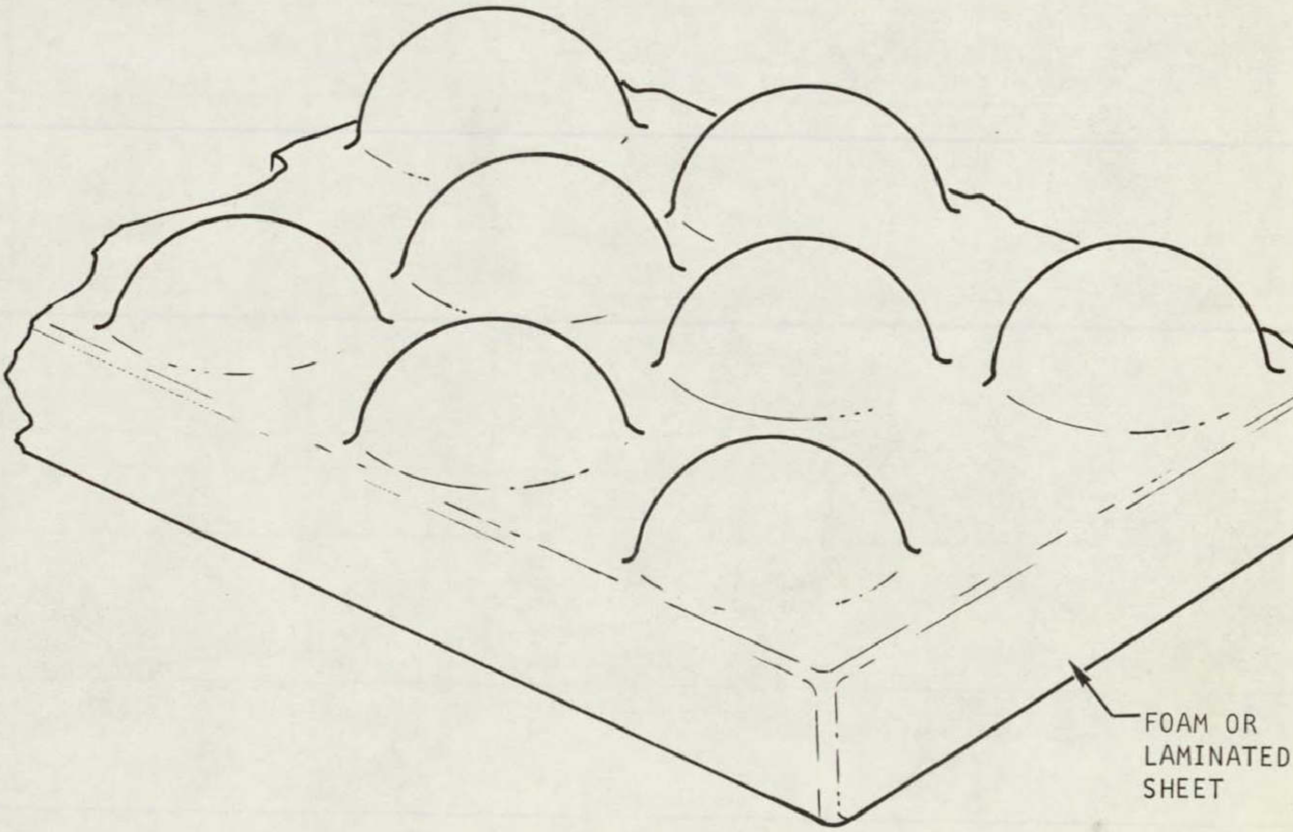


Figure 7-17. Ceiling/Floor Material



a. Convoluted Foam



b. AirPac

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Figure 7-18. Floor Covering with Properties for Acoustics, Traction, and Cushioning

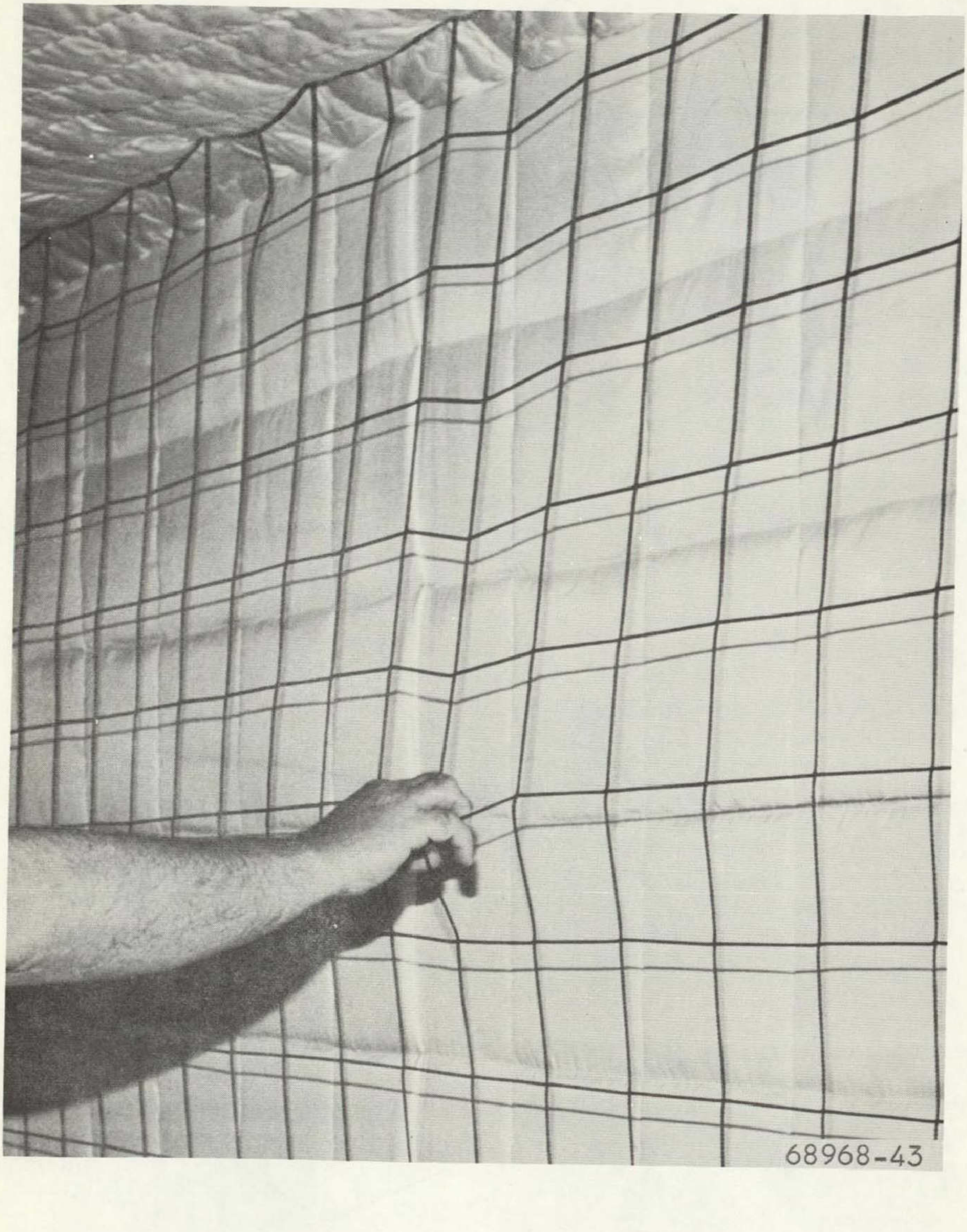


Figure 7-19. Netting Wall Material that Effects Mobility

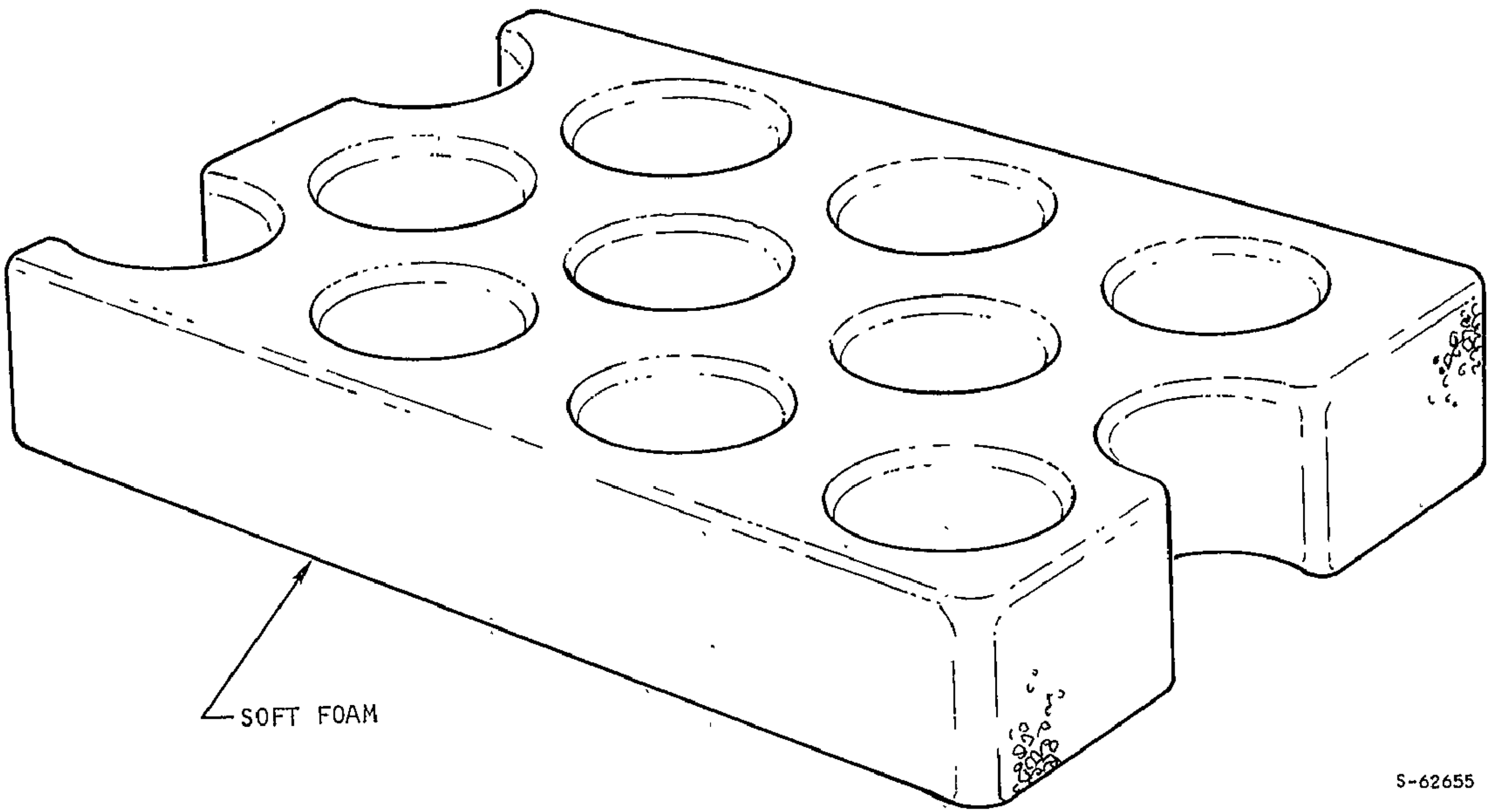


Figure 7-20. Alternate Floor Material

Although all of these versions appear promising, they must be tested in zero-g flight to accurately define the advantages and disadvantages of their use for spacecraft interiors.

Color accents can be provided by small irregular styrofoam forms that can be released to float about in zero-g. As they float about, change their relationship with each other, and turn different colored sides to the observer, visual interest is created similar to that created by the mobiles of Alexander Calder. Mixing textures, such as one side dull and the other highly reflective or smooth and colored, will add another element of interest. Use of lightweight foam-type material makes it easy to play games with them or just push them aside.

Creative interior color schemes can be achieved by crewmembers with artistic experience using nonpermanent media on the walls. Drawings, sketches, arrangement of shapes, or the juxtaposition of color can all be done for pleasure and the relief of monotony. The use of nonpermanent materials permits the arrangement to be changed at will. Artistic learning should improve by practice and change, and if the idea is not a good one, it can easily be altered. The crewmember will simply clean the walls and start over.

Photographs selected by the crew member can be arranged as he desires and fastened to the interior with double-face tape or mounting tabs. By using double-face tape, pictures may be rearranged, replaced, or discarded according to individual desires.

CONCEPTUAL CRITERIA

Conceptual criteria and standards for the privacy area are listed below. For each criterion, a standard is recommended in the opposite column.

TABLE 7-3

SLEEP AREA CONCEPTUAL CRITERIA

Criteria	Standards
1. Provide area and volume adequate to accommodate one man, space suit, backpack, personal equipment, bed; and adequate room to don suit and pack in the event of emergency.	1. A 250-cu ft volume has been generated based on mobility requirements for pressure suit donning. A floor area of 38.5 sq ft minimum is recommended.
2. Provide for the consolidation of sleeping areas.	2. Removable modular walls that are expandable or inflatable.

TABLE 7-3 (Continued)

Criteria	Standards
3. Adequate lighting must be available to allow reading.	3. Provide portable high-intensity light of 100 ft-c.
4. Ambient light must be variable.	4. Provide light dimming control of 0 to 30 ft-c.
5. Locate sleep area on a different level from operations or at the most distant position from it if a one-level capsule is used.	5. Provide noise dampening and sound level control.
6. Ceiling can be located out of reach to provide a feeling of maximum space.	6. A height of 6-ft 6-in. is required for zero-g mobility (walking).
7. If ceiling does not attach to interior walls, a more expansive spatial feeling is obtained.	7. Create gaps between wall and floor and wall and ceiling when noise is not a problem.
8. Construct to reduce operational noises.	8. Interior should be designed to reduce operational noises (NASA specification).
9. Provide more luxurious surroundings to differentiate from work areas.	9. NASA-approved materials only.
10. Use odorless materials in construction.	10. NASA-approved fiberglass, etc.
11. Materials and finishes may be varied and more "homey".	11. Provide perceptual richness by using dichromatic finishes, wood veneer, etc.
12. Provide selection of colors.	12. Wall panels are modular in construction and are of a different color on each side.
13. Provide individual ventilation control in each separate area.	13. Vent control switch.
14. Provide soft walls and furnishings to prevent injury or damage due to zero-g stability conditions.	14. NASA-approved materials for interior and furniture padding.

TABLE 7-3 (Continued)

Criteria	Standard
15. Provide alarm for arousing crew.	15. Klaxon or other unique sound that can not be mistaken for anything but an emergency.
16. Provide a means for telling time.	16. Digital clock--minutes, hour, day, month, year.
17. Provide seating restraint for writing.	17. Flexible, stackable type.
18. Provide writing materials.	18. Clipboard with restraint and light.
19. Provide restraint for visitors.	19. Flexible, stackable type.
20. Be able to rapidly retrieve spilled liquids.	20. Liquid retriever.

FUNCTIONS ANALYSIS

Second-Level Functions

A functional diagram for providing privacy (fig. 7-21) was developed primarily to structure compartment requirements into preliminary actions that would be accomplished by space station personnel and equipment. Since only the privacy area, wardroom, and hygiene area are discussed in this report, this functions analysis is not final. This preliminary analysis can be completed only when it is incorporated into a total mission functions analysis.

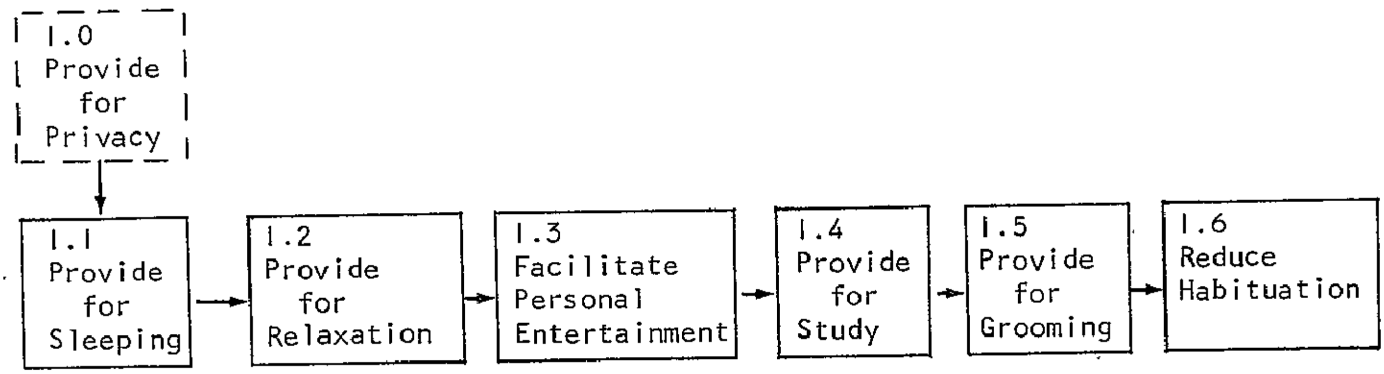


Figure 7-21. Second-Level Functions for Sleep Station

Block 1.1--Provide for Sleeping

Adequate rest must be provided for all crew members to ensure efficiency during long-duration space missions. Reduced sleep over extended periods of time can lead to increased hostility between crew members. Loss of sleep also can reduce individual accuracy and increase the time required to perform routine tasks. In addition, sleep is necessary to maintain individual resistance to bacteria and other forms of infection. Prevention of disease is very important to mission success.

Block 1.2--Provide for Relaxation

Relaxation depends upon the individual and the type of work being performed If the normal task is precise close work that is tension-producing, an opposite activity for relaxation should be considered and vice versa. For example, a crew member who reduces data collected during experiments should be encouraged to listen to music or pursue some form of relaxation that does not require reading or analyzing complex technical information. Too much of one activity, even though pursued voluntarily by an individual, can lead to tension and result in crew dissension. Another good method for reducing tension and achieving relaxation is physical exercise. However, physical exercise should not be used to achieve relaxation by an individual who has expended a great deal of energy performing EVA during the working day.

Block 1.3--Facilitate Personal Entertainment

Personal entertainment is an important aspect of habitability for long-duration space flight. Personal entertainment is important because it helps to relieve feelings of frustration, boredom, and depression. The privacy of the individual sleep station allows each crew member to experience a particular type of entertainment that other crew members would not like to experience. For instance, one of the crew might enjoy jazz music. If other people in the wardroom do not want to hear jazz music, the person wanting to listen to jazz music can do so in his privacy area without distracting or antagonizing the other crew members.

Block 1.4--Provide for Study

A quiet area is preferred by most people who want to study particular subjects. The personal sleep station provides the necessary atmosphere for individual study. A crew member wishing to study some particular aspects of an extravehicular task planned for the next work day should be able to do so without distraction from other personnel or equipment.

Block 1.5--Provide for Grooming

Although grooming is not essential to health, it is necessary to maintain feelings of well-being that have become associated with grooming acts encouraged by society. An astronaut who wants to shave or keep his hair cut and clean should be provided with the facilities to do so. Grooming for particular individuals will help minimize feelings of tension and anxiety. Since grooming is commonly performed in privacy, the personal compartment should accommodate this activity. Long hair and beards are not suited for wear in the current space suits.

Block 1.6--Reduce Habituation

Habituation must be held to a minimum during long-duration space flight. Numerous isolation studies have shown that habituation is very deleterious to efficient human performance. Changing stimuli are essential to normal sensory-motor and central nervous system functioning. Since the spacecraft and zero-g environment provide limited sensations as compared to the wide range of sensations that can be experienced during earthbound living, design considerations for reducing habituation become of paramount importance. Reduction of rate of habituation can be accomplished by strategies to achieve perceptual richness in the privacy area.

Third-Level Functions

Provide for Sleeping

The function to provide for sleeping can be subdivided for implementation into third-level functions as shown in fig. 7-22. Further division of these

third-level functions results in the tasks that are delineated in the task analysis discussion of this section.

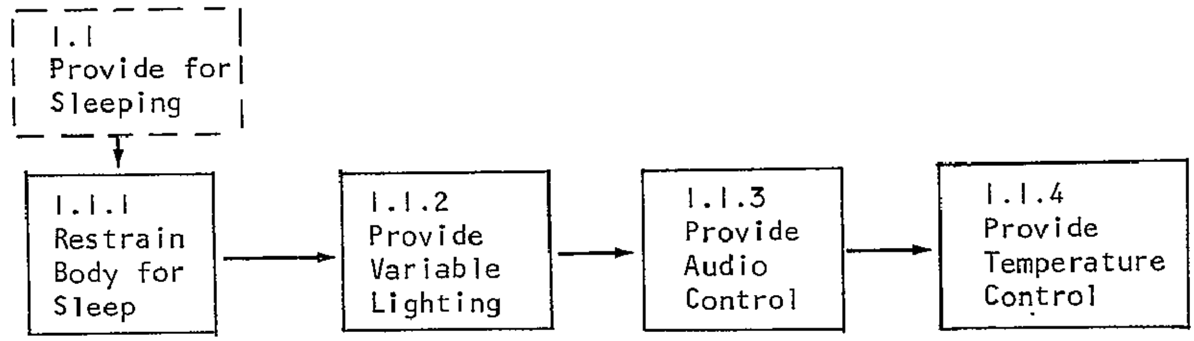


Figure 7-22. Third-Level Functions for Sleeping

Block 1.1.1--Restrain body for sleep.- The sleep restraint should be able to do the following:

(1) Retain crew members comfortably in all normal sleeping positions while in zero-g.

(2) Allow easy and rapid entrance and exit.

(3) Be moved easily to other locations within the spacecraft.

(4) Maintain comfortable body temperature for sleeping.

(5) Accommodate a pressure-suited crew member.

(6) Provide appropriate tactile sensations.

Information from previous flights indicates that a cocoon-like sleeping restraint should be used. A device of this configuration improves the ability to control sleeping temperature and to provide a degree of privacy.

Block 1.1.2--Provide variable lighting.- To change light intensity, individually controlled, subdued night lighting should be provided within the sleeping compartment. Individually controlled lighting will allow each crew member to set the light intensity that he prefers. Those wanting total darkness can sleep in total darkness, while those preferring to sleep with some light can do so. Also, to prevent disturbance of crew member rest, ambient lighting in corridors and passageways should not be allowed to enter the sleep area.

Block 1.1.3--Provide noise control.- Noise generated outside of the sleep area must be controlled so that it does not interfere with or prevent crew members from resting. Some provisions might be made for auditory sounds that help induce sleep for those preferring it. Music could be played and turned off automatically after a predetermined time period. Sounds from emergency alarms must not be prevented from entering the sleep area and must be easily distinguished in pitch, tone, and intensity.

Block 1.1.4--Provide temperature control.- Air temperature control devices should be located in each separate sleep compartment, thereby allowing each crew member to maintain a temperature that he finds suitable. Also, a thin, lightweight blanket or liner should be provided for sleeping and resting. In addition to maintaining a comfortable sleeping temperature, the blanket could enhance tactile resting sensations normally experienced on earth.

Facilitate Personal Entertainment

Entertainment is closely related to relaxation and should include provisions for individual aesthetic pursuits (music, reading, writing), one-man games (solitaire), and games that require more than one person (chess). The third-level entertainment functions are shown in the logic diagram of fig. 7-23.

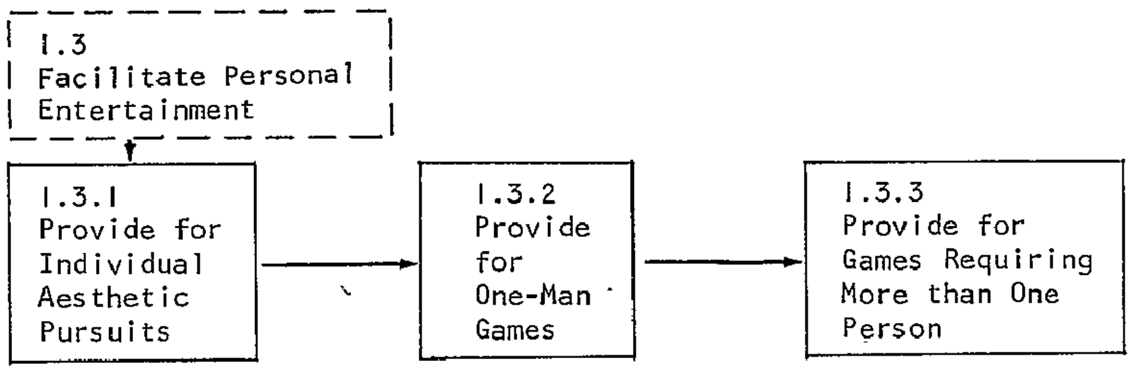


Figure 7-23. Entertainment Third-Level Functions

Block 1.3.1--Provide for individual aesthetic pursuits.- Past studies have shown that crews confined for long periods of time soon exhaust superficial recreation devices such as games, models, etc. and turn to more creative pursuits; some paint, music has been composed, and poetry written. Equipment and space for these creative pursuits must be provided for crew self-expression.

Block 1.3.2--Provide for one-man games.- One-man games should be provided for those instances where crew members prefer to be alone and yet desire some form of amusement. One-man games will provide contrast for those not interested or saturated with creative pursuits, thus allowing one more avenue for eliminating boredom.

Block 1.3.3--Provide for games requiring more than one person.- Games that require few participants (cards, chess, etc.) should be provided for use in personal compartments where concentration can be achieved. This also provides a relief from wardroom community activities such as movies. Small group desires can be fulfilled by this flexibility while freeing the wardroom for other activities or just "changing the scene."

Provide for Study

The provide for study function can be further divided into the third-level functions shown in fig. 7-24. Provisions must be made for reading, writing and sketching, restraint, local illumination, and recall of information.

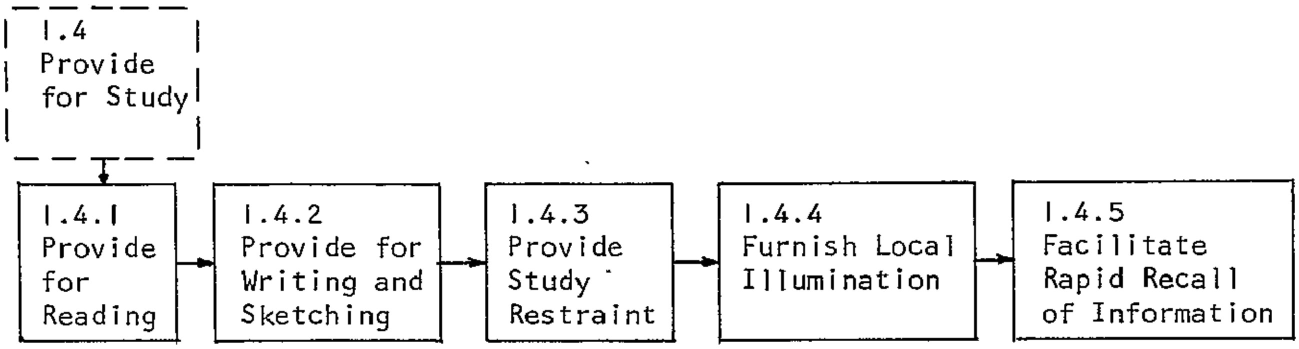


Figure 7-24. Third-Level Study Functions

Block 1.4.1--Provide for reading.- Each astronaut should be able to read written materials in the privacy of his sleep station. Reading experimental results, hypotheses of colleagues, or equipment design configurations are but a few important reading tasks that must be accomplished during study.

Block 1.4.2--Provide for writing and sketching.- Writing and sketching capability also must be provided in the privacy area. Many people need to formulate concepts and ideas in their own writing before they can understand fully what concept is being advanced. They also need to write or sketch their own innovations before the association fades and the idea is forgotten.

Block 1.4.3--Provide study restraint.- In the zero-g environment, all study materials should be restrained. The astronaut also should be restrained to preclude distractions caused by movement away from the study materials or continued efforts to keep a satisfactory position in relation to the study materials. In addition, equipment stowed for future use must be restrained.

Block 1.4.4--Provide local illumination.- A local source of illumination should be maintained for study. The astronaut and study material could be fixed in relation to this illumination, or the illumination source could be fixed to the astronaut/study material configuration. The local illumination should be placed such that shadows on the study material are precluded. This illumination also must be of the intensity and color that is best for minimizing eye strain. The crew members should be able to adjust this lighting level to suit their needs (30 to 100 ft-c).

Block 1.4.5--Facilitate rapid recall of information.- Rapid recall of information is mandatory in cases of emergency that require quick decisions based on accurate data. Tape recorders can be used for storing study information and providing other information such as detailed technical instructions. An audio-visual device is desirable as a readout for information of all types stored for rapid retrieval and individual use. Storage information can range from scientific data and maintenance information to entertainment (music and poetry). Fast computation can be achieved by incorporating a keyboard and on-line capability; this would provide a complete information center capable of storing large quantities of information for rapid retrieval.

Provide for Grooming

The provide for grooming function can be subdivided into third-level functions for restraining personal effects, dressing and undressing, and performing dry hygiene. These functions are shown in fig. 7-25.

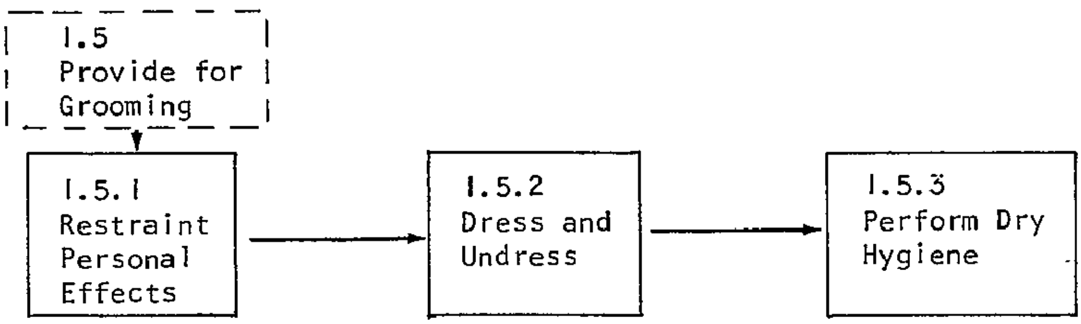


Figure 7-25. Third-Level Grooming Functions

Block 1.5.1--Restrain personal effects. - All personal possessions taken aboard must be restrained in the zero-g environment but remain easily and readily accessible. Space must be provided for the possessions of replacement crew members during the changeover period.

Block 1.5.2--Dress and undress.- Space must be provided in the privacy area for dressing and undressing. The maximum amount of space that would be required for this function would occur when doffing and donning the pressure suit in cases of emergencies.

Block 1.5.3--Perform dry hygiene.- Dry hygiene includes body care tasks that do not require the use of water. Examples of dry hygiene are electric shaving, hair and nail maintenance, washing with disposable wipes, and oral hygiene by using a consumable dentifrice. Provisions must be made for entrapment and retention of body hair and nail growths that are periodically trimmed.

Reduce Habituation

The reduce habituation function can be subdivided into the third-level functions of change space, change lighting color, and change compartment appearance. These third-level functions are shown in fig. 7-26.

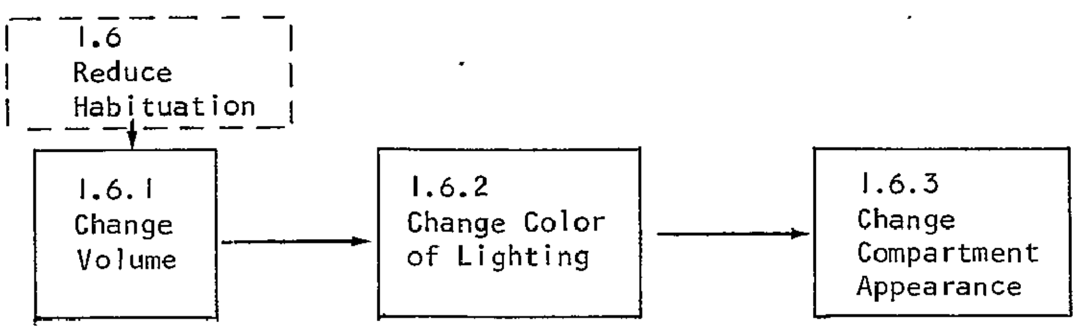


Figure 7-26. Third-Level Functions for Reducing Habituation

Block I.6.1--Change Volume. - Movable walls provide the capability of rearranging the privacy area to suit individual tastes. Two or more crew members can occupy the same compartment by removing a wall between two sleep areas to enlarge the space. If this arrangement becomes undesirable, the privacy area can be returned to its original size, or other alternatives can be explored. The ability to change the space is perhaps the easiest method of eliminating boredom. Sharing sleeping quarters is a tradeoff because privacy is forfeited, and should be done only with the consent of all parties.

Block I.6.2--Change color of lighting.- Changing the color of the ambient lighting will radically alter the appearance of the compartment. Colors of fixed objects within the compartment can be changed to almost full complements by varying the lighting. One lighting color tradeoff is the ghastly appearance cool colors (blues and greens) have on human flesh. People, especially blondes, look mortified; however, warm colors (reds and yellows) cause them to look young and vibrant. Mixing the colors from separate fixtures creates interesting effects.

Block I.6.3--Change compartment appearance.- The visual aspect of the compartment can be changed by changing or removing pictures from the walls (Chinese practice). Another approach is to vary the color scheme. Rotating wall panels that have a different color on the back side is one approach. Another is the use of contact-type papers that can be purchased in a wide variety of colors and patterns, including wood grains. Wood will provide an interesting relief from the hard-metal and plastic surfaces. Choice of color is highly subjective, and the flexibility to change the (privacy area) colors to suit the individual will be a great deterrent to boredom. Removable pigments may be supplied to permit individual creations in the form of murals or wall decorations.

TASK ANALYSIS

To further delineate privacy area requirements for space station personnel, tasks to be performed by these personnel in the privacy area are described in the following task analysis forms (fig. 7-27). As is the case for the functions analysis, these tasks are preliminary. When functions are reduced to the level where the next step involves the manipulation of equipment, they become tasks (i.e., turn on audio device). Tasks and equipment can be finalized only after a total mission has been defined and studied. Task analysis forms have been completed for each privacy function discussed in this section. The information loop is shown beginning with the task description information in, decision, and feedback. Performance deviations are the likely result of occurrences if the event does not proceed normally. Additional equipment includes those items such as hand tools that must be used to bring about the stated events. The location in the craft, frequency of occurrence, and elapsed time are all entered on this form. General items are carried in the remarks column along with an estimated volume of the hardware being considered.

1.1 PROVIDE FOR SLEEPING

TASK ANALYSIS OF: RESTRAIN BODY FOR SLEEP
3RD LEVEL FUNCTION NO: 1.1.1

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Prepare sleep restraint unit	SA	Once each 24 hr			Schedule or preference	Open sleep restraint by grasping opposing flaps at top and pulling	Visual, tactile Velcro releases by pulling motion and restraint is opened	Unit does not open Delay or possible loss of rest	Inner liner or blanket may be required	Unit (sleeping bag) design must provide easy and rapid entry and exit. Failure must not occur in order to assure crew performance and safety
	Enter sleep restraint unit	SA	Once each 24 hr	30 sec		Sleep restraint unit is open	Place feet and torso in restraint unit in a comfortable position	Visual, tactile Limbs and torso inside restraint unit	Unable to complete entry Delay, causing loss of sleep or rest		
	Fasten restraint unit	SA	Once each 24 hr	15 sec		Torso and limbs inside restraint unit	Grasp opposing flaps and press together to seal restraint	Visual, tactile Velcro seals by pressing together	Unit does not fasten Delay, causing loss of sleep or rest		
	Exit from sleep restraint	SA		30 sec		Sleep complete, or schedule, or emergency	Grasp opposing flaps and pull apart to break seal and open bag	Visual, tactile audio Restraint opens as velcro separates	Unable to complete exit May cause schedule delay, possible hazard in emergency		
	Close sleep restraint unit	SA	Once each 24 hr	15 sec		Restraint is open	Grasp opposing flaps and press resealing bag in the closed position	Visual, tactile Velcro seals when pressed together	Unit does not close Sleep restraint must be closed for protection and not to impede mobility		

Figure 7-27. Task Analysis

TASK ANALYSIS OF: PROVIDE VARIABLE LIGHTING,

1.1 PROVIDE FOR SLEEPING

3RD LEVEL FUNCTION NO: 1.1.2

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Adjust lights for intensity	Privacy area		15 sec		Schedule or preference	Set light level to preferred position Variable control	Visual, tactile	Lights cannot be adjusted		Basic lighting should be variable to permit adjustment to various levels to suit individual sleep needs.
								Illumination level varies to off position as control is operated	Sleep may be impaired		

Figure 7-27 (Continued)

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Isolate external noise	Sleep area	Random	30 sec		High noise level	Eliminate noise Close compartment door	Audio, visual	Door does not close		Noise will be detrimental to rest
								Door closes and latches/ External noise is eliminated	Will prevent compartment isolation from external noise		
	Adjust normal audio communication system	Sleep area	Random	5 sec		Compartment door closed	Set volume to desired level	Visual, audio	Communications cease	Maintenance tools	
								Normal communication transmissions: on light is on	Will require repair or replacement Malfunction display		
	Activate emergency communication system	Sleep area	Random	2 sec		Normal communication system off	Set emergency communication system switch to on position	Visual	Emergency cannot be sounded		Isolation of sleep area from normal operational noise is necessary to ensure adequate rest and relaxation. Provisions should be made to include an emergency communication system that, is normally in a passive condition. Emergency conditions will be sounded in the sleep area at any time. A control is provided for the crew member to signal an emergency to the other areas of the spacecraft.
								On light is activated	Will require immediate repair or replacement because the spacecraft may be lost if emergency conditions cannot be sounded		

Figure 7-27 (Continued)

TASK ANALYSIS OF: PROVIDE TEMPERATURE CONTROL,
3RD LEVEL FUNCTION NO: 1.1.4

1.1 PROVIDE FOR SLEEPING

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Adjust temperature	Privacy area	Random	15 sec		Preference	Set temperature to preferred level variable control	Visual, tactile	Temperature does not change		Individual control of temperature in the sleep area is considered necessary due to the wide range of personal preference, particularly during times of rest or sleep. Minor fluctuations of the temperature will lessen habituation.
								Individual comfort attained Quantitative temperature readout.	Will require repair or replacement of control unit		

Figure 7-27 (Continued)

TASK ANALYSIS OF: PROVIDE FOR RELAXATION

I. PROVIDE FOR PRIVACY

2ND LEVEL FUNCTION NO: 1.2

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Relax while off duty	Privacy area	Daily	2 to 3 hr		Scheduled tasks have been completed	Select a diversionary means of self satisfying activity. Reading, writing sketching or participating in group games or sports.	Audio, visual, tactile. Feeling of well being	Unable to relax. Dangerous sociological and psychological overtones	Reading, writing, or sketching materials. Sleep area including restraint both seated and supine.	Crewmen are free to select a method of relaxation that best satisfies their needs.

Figure 7-27 (Continued)

TASK ANALYSIS OF: PROVIDE FOR INDIVIDUAL AESTHETIC PURSUITS,
3RD LEVEL FUNCTION NO. 1.3.1

1.3 FACILITATE ENTERTAINMENT

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Draw and sketch pictures	Privacy area	Random	0 to 7 hr daily		Scheduled off-duty time	Satisfy creative needs	Visual, motor, tactile	Frustration and boredom results	Sketch pad and dry colors (11 in. by 14 in. by 1/2 in.) pad (12 in. by 5 in. by 3/4 in.) colors	Audio background music may be preferred.
	Compose music	Privacy area	Random	0 to 7 hr daily		Scheduled off-duty time	Implement creative urge	Visual, tactile	Frustration and boredom results	Music pad Music pen (sealed) (8-1/2 in. by 11 in. by 1/4 in.) pad. (5 in. by 1/2 in. dia pen)	Supplies required only for musicians.
	Creative writing (poetry, novels, etc.)	Privacy area	Random	0 to 7 hr daily		Scheduled off-duty time	Document creative thoughts	Visual, tactile	Frustration and boredom results	Pad and writing tool (8-1/2 in. by 11 in. by 1/4 in. pad)	
	Play musical instrument	Privacy area	Random	0 to 7 hr daily		Scheduled off-duty time	Make music	Audio, tactile, motor, visual	Frustration and boredom results	Specified small, lightweight musical instruments	Instruments should be provided for accomplished musicians only.

Figure 7-27 (Continued)

TASK ANALYSIS OF: PROVIDE FOR ONE-MAN GAMES,
3RD LEVEL FUNCTION NO: 1.3.2

1.3 PROVIDE FOR ENTERTAINMENT
(Example - Cards)

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Open storage compartment	Privacy area	Random as desired by indi-vidual	10 sec		Preference for entertainment	Select storage compartment	Visual, tactile Positive opening latch	Latch malfunction Will delay task		
	Select game cards	Privacy area	Random as desired by indi-vidual	2 sec		Display of cards	Make selection from games provided.	Visual Availability quantity and type	Non availability Will affect recreation activities		
	Remove from storage	Privacy area	Random as desired by indi-vidual	4 sec		Selected cards	Remove cards from storage	Visual, tactile	Cards cannot be removed or are missing. No entertain-ment or delay.		
	Set up playing surface	Privacy area		2 min		Gravity condition (zero-g)	Attach surface cover	Visual, tactile Cover attaches by Velcro or snaps	Cards are not restrained Game is delayed		Special cover and cards will be required as restraints in the zero-g condition
	Restrain torso	Privacy area		5 sec		Equipment setup	Assume playing position and fastens restraint	Visual, tactile Body is restrained at game place	Restraint does not fasten Delay of game		
	Adjust lighting	Privacy area		4 sec		Illumination not at desired level	Adjust illuminating to suit	Visual Cards are easily seen by all	Switch malfunction Delay or unable to play		
	Proceed with game	Privacy area		0 to 7 hr when off duty		Game rules					

Figure 7-27 (Continued)

TASK ANALYSIS OF: PROVIDE FOR GAMES REQUIRING MORE THAN ONE PERSON,
3RD LEVEL FUNCTION NO: 1.3.3

1.3 PROVIDE FOR ENTERTAINMENT
EXAMPLE -- CHESS

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Open storage compartment	Privacy area	Preference group random	10 sec		Preference for group entertainment	Activate latch and open door	Visual, tactile Positive opening latch-door opens	Latch malfunction Will delay task		
	Select game set	Privacy area	Preference group random	2 sec		Display of games	Make selection	Visual Availability	Non availability Will affect recreation activities		
	Remove from storage	Privacy area	Preference group random	4 sec		Selected game	Grasp components and remove	Visual, tactile			
	Setup game	Privacy area	Preference group random	2 min		Gravity conditions (zero-g)	Position game set	Visual, tactile Game set including chess pieces are in proper place	Improper setup		Chessboard and chess pieces should be designed to be compatible with zero-g. For example, chess pieces may be fitted with Velcro on bottom and board made with Velcro surface. Two sets of restraints are required, one for each player permitting them to face each other for the game.
	Restrain torso	Privacy area	Preference group random	5 sec		Setup complete	Fasten restraint	Visual, tactile Body is restrained at playing place	Unit does not fasten Delay of game, possible cancellation of game		

Figure 7-27 (Continued)

TASK ANALYSIS OF: PROVIDE FOR READING,
3RD LEVEL FUNCTION NO. 1.4.1

1.4 PROVIDE FOR STUDY

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Procure study material	Privacy area	Random off duty	2 to 5 min		Personal preference	Select the desired material	Visual, tactile Cartridge or keyboard	Desired material unavailable Boredom	Audiovisual device (25 in. by 20 in. by 14 in.)	One audiovisual device can be used for all types of reading; keyboard provides computer capability.
	Turn on audio-visual device	Privacy area	Random off duty	4 sec		Desired material selected	Study selected subjects	Audiovisual	Study is delayed until repair is made.		
	Study subject matter	Privacy area	Random off duty	0 to 7 hr		Subject material presented on vidio device	Study at individually selected rate of speed.	Audiovisual	Rate too slow, will result in boredom. Rate to fast, information will be missed.		
	Restrain body for reading	Privacy area	Random off duty	0 to 7 hr		Reading material being presented on audiovisual device.	Fasten restraint	Normal reading distance is maintained	Disorientation will result if the observer rotates in relation to the display		

Figure 7-27 (Continued)

TASK ANALYSIS OF: PROVIDE FOR WRITING
3RD LEVEL FUNCTION NO: 1.4.2

1.4 PROVIDE FOR STUDY

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Open storage compartment	Privacy area				Schedule or preference	Activate latch and open door	Visual, tactile Positive opening latch	Latch malfunction Will delay task		A clipboard with built-in light and restraint will permit writing in any attitude throughout the craft.
	Select writing material	Privacy area				Display	Select pad and writing implement	Visual Availability quantity and type	Inadequate material available May affect crew morale, could delay scheduled mission functions	Pad (8-1/2 in. by 11 in. by 1/4 in.) writing tools (6-1/2 in. by 1/4 in.)	
	Remove material from storage	Privacy area				Selected material	Grasp material and remove from storage compartment	Visual, tactile	Material damaged Possible limitation of task	Clipboard with light	
	Restrain torso	Privacy area				Necessary materials are all gathered.	Fasten restraint	Visual, tactile Restraint fastens by pressing Velco parts together	Unit does not fasten Will cause delay		
	Adjust lighting	Privacy area				Preference	Focus light to desired area and adjust to desired intensity	Visual Intensity and/or color changes as switch is manipulated in accordance with procedures	Switch malfunction Will require repair or replacement, will delay task	Local light source required.	

Figure 7-27 (Continued)

1.4 PROVIDE FOR STUDY

TASK ANALYSIS OF PROVIDE STUDY RESTRAINT,
3RD LEVEL FUNCTION NO: 1.4.3

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Restrain body for study	Privacy area	Random	0 to 5 hr		Personal choice or required	Read and or write as desired in the seated or horizontal position	Audiovisual		Portable	
								Audiovisual device for reading and pad and pen for writing	Discomfort or disorientation if the body moves and rotates about display	Seated restraint	Sleeping restraint will provide horizontal restraint

Figure 7-27 (Continued)

TASK ANALYSIS OF: PROVIDE LOCAL ILLUMINATION
3RD LEVEL FUNCTION NO: 1.4.4

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Turn on light	Privacy area				Preference	Activate switch to on position	Visual	Switch malfunction		
								Illumination results when switch is on	Will require repair or replacement		
	Adjust light direction	Privacy area				Preference	Swivel or direct light beam to desired area	Visual	Directional mechanism malfunctions		Individual or localized lighting. Should be sure that direction, intensity and color may be changed to satisfy personal preference and provide utility within the privacy area
								Desired area is lighted	May require postponement of task until repair is made		
	Adjust light intensity	Privacy area				Preference	Increase or decrease intensity to desired level	Visual	Control mechanism malfunction		
								Intensity changes as central mechanism is moved in appropriate direction	May affect task performance		

Figure 7-27 (Continued)

1.4 PROVIDE FOR STUDY

TASK ANALYSIS OF: FACILITATE RAPID RECALL OF INFORMATION,
3RD LEVEL FUNCTION NO: 1.4.5

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Activate audio-visual system	Privacy area				Schedule or preference	Place power switch to ON position	Visual, tactile	Switch malfunction		Audiovisual device approximately 25 in. by 20 in. by 14 in. One device can be used as a terminal for all audiovisual presentations. A key board can be added to provide computer capability. No commerical device with these characteristics is presently known, but it is well within the state of the art.
								ON light is illuminated	Will cause delay-repair will be required		
	Select study item	Privacy area				Display is on	Select video tape	Visual	Nonavailability		
								Availability	Will delay task completion		
	Load tape	Privacy area				Tape selected	Lock tape into position	Visual	Tape does not lock correctly		
									Will delay task. Possibly cause loss of study lesson		
	Start tape	Privacy area				Tape in position	Activate start switch	Visual, auditory	Video or audio system mal-function		
								Tape runs and system provides video image and sound	Will delay task Repair or replacement of components required		
	Adjust audio and video	Privacy area				Preference	Adjust video to desired clarity and adjust audio to desired volume	Visual, auditory	Desired adjustment cannot be made		
								Clear image and satisfactory sound level is produced by system			

Figure 7-27 (Continued)

1.5 PROVIDE FOR GROOMING

(Example - work garment)

TASK ANALYSIS OF: RESTRAIN PERSONAL EFFECTS,
2ND LEVEL FUNCTION NO: 1.5.1

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Prepare garment for storage	Privacy area				Initial supply, resupply, or after laundry	Fold or roll garment to fit storage device	Visual, motor, tactile	Garment not folded correctly	Storage compartment (12 in. by 24 in. by 36 in.)	
						Garment inspected for maintenance and repair		Garment is capable of being stowed	Will not stow-- Will not require correction	Garment repair kit (3 in. by 5 in. by 3/4 in.)	
	Place in storage compartment	Privacy area				Garment folded	Grasp garment and insert in appropriate compartment segment	Visual			Personal storage compartment will be sized to accept all items on the basis that exact storage procedures are followed Garments should be inspected and maintained after laundry or as necessary
								Garments are all stowed for easy rapid access	Improperly stowed garments will result in crew inefficiency and possible hazard if loose in zero g		

Figure 7-27 (Continued)

1.5 PROVIDE FOR GROOMING

TASK ANALYSIS OF: DRESS AND UNDRESS

2ND LEVEL FUNCTION NO: 1.5.2

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Dress. Put on underwear	Privacy area	Daily	2 min		Schedule, or sleep completed.	Arise and don underwear. Remove from "0" g holder	Visual, tactile Underwear is properly donned	Underwear not available	Zero-g holder: 4 in. by 12 in.	
	Don outer garments	Privacy area	Daily	3 min		Underwear is properly donned.	Finish dressing Remove outer garments from "0" g holder.	Visual, tactile Clothing is properly donned	Clothing is not available	Zero-g holder 5 in. by 17 in by 12 in. Donning volume 75 in. high by 30 in. dia by 42 in. wide	
	Don space suit	Privacy area	Random emergency	10 min		Emergency - Don proper undergarment	Don pressure suit without delay Remove from storage container	All senses Suit is pressurized providing a mobile environment	Pressure suit cannot be donned in time *Death may result	Pressure suit donning volume 75 in. by 42 in. by 51 in.	*Pressure suit must be properly maintained and stored in a protective container for easy rapid donning in case of emergency
	Doff space suit	Privacy area	Random emergency	10 min		Emergency has subsided	Remove pressure garment, perform maintenance, and store for future use	Visual, tactile, audio Suit is stowed in container	May not be usable when required. *Possible loss of life	Doffing volume 75 in. by 42 in. by 51 in., same as donning	Suit must be maintained after each use.
	Remove outer garments	Privacy area	Daily	3 min		Change clothes or prepare for sleep.	Remove and stow outer garments	Visual, tactile Clothes properly stowed in "0" g holder	Sleep in clothes or clothes float about. Vents may be covered, etc.	Zero-g clothes holder	Loose items of clothing should not float about the interior.

Figure 7-27 (Continued)

TASK ANALYSIS OF: PROVIDE FOR DRY HYGIENE,
2ND LEVEL FUNCTION NO. 1.5.3

I. PROVIDE PRIVACY

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Superficial bathing	Privacy area				Preference	Obtain disposable wash cloth from storage	Tactile, physiological	Cloths not available	Personal equipment storage	It is anticipated that personal hygiene in the privacy area will be limited to those items that can be accomplished with personal equipment stored in the privacy area and do not require use of water.
								Hands and other exposed parts are cleaned thoroughly	Failure to clean body may become a health hazard and be offensive to others	Kleen wipes, wash-dry (packaged wash cloths)	
	Shaving	Privacy area				Personal need	Obtain razor from storage	Visual, tactile	Razor inoperative	Electric type razor	
								Razor operates adequately	Failure may affect personal appearance and comfort		
	Brush or comb hair	Privacy area				Personal need	Obtain comb or brush from storage	Visual, tactile	Comb or brush not available	Brush or comb	
									Failure to do so may affect personal appearance		

Figure 7-27 (Continued)

1.6 ELIMINATE HABITUATION

TASK ANALYSIS OF: CHANGE SPACE, 3RD LEVEL FUNCTION NO: 1.6.1

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Rearrange furnishings	Privacy area	Random	15 min		The desire for change	Select the items to be moved and a new location for each	Visual, tactile, psychological Pleasant arrangement of furnishings	Habituation leads to boredom		Modular design permits the rearrangement of furnishings.
	Enlarge living space	Privacy area	Random	15 min		The desire for larger quarters	Give up privacy for space by sharing sleeping area with another crew member; remove wall separating cubicles	Visual, audio, psychological Enlarged space provides needed change			Walls between compartment must be movable--can use inflatable, folding or modular panels.

Figure 7-27 (Continued)

1.6 ELIMINATE HABITUATION

TASK ANALYSIS OF: CHANGE COLOR OF LIGHTING,
3RD LEVEL FUNCTION NO.: I 6.2

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Change color of ambient	Privacy area	As desired	1 min		Desire for change	Select a new color for the interior	Visual, psychological Pleasing color scheme in privacy area (switch)	Habituation leading to boredom		Lights must have the capability of changing from warm to cool colors and providing a mix of these colors.
	Change intensity of lighting	Privacy area	As desired	30 sec		Functional requirement	Select appropriate light level for individual needs	Visual, psychological Lighting intensity suits the task (rotary control)	May interfere with sleep if lights cannot be dimmed		Ambient lights should be controllable from off up to their peak intensity.

Figure 7-27 (Continued)

1.6 ELIMINATE HABITUATION

TASK ANALYSIS OF: CHANGE COLOR APPEARANCE
3RD LEVEL FUNCTION NO: 1.6.3

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Change interior colors	Privacy area	As desired	15 min		Desire for change	Create new visual excitement by changing interior colors	Visual, psychological Pleasing compartment	Habituation leading to boredom. Dislike for quarters resulting in inefficient work habits		Modular panels can be reversable with different colors on each side.
	Change interior texture	Privacy area	As desired	15 min		Desire for change	Change texture	Visual, psychological Pleasing compartment	Habituation		Panels can have fabric of varying texture on each side.
	Change interior appearance	Privacy area	As desired	1 to 40 hr		Desire for visual relief and change	Create wall patterns for mural	Visual, psychological Creative expression resulting in a pleasing interior		Dry colors that can be temporarily fixed but removed at will. (pastels and fixative or wax crayons and removal fluid)	Decorating their compartment to suit is an excellent creative outlet. Media used must be removable in case of error and to allow change and reduce habituation.

Figure 7-27 (Continued)

SECTION 8

HYGIENE AREA STUDY

8

HYGIENE AREA STUDY

DESIGN RATIONALE

Hygiene encompasses all aspects necessary to maintain cleanliness and health including body cleaning, garment cleaning, mouth cleaning, shaving, hair cutting, nail care, and body waste management (urine, feces, vomitus, mucous, hair, nails, etc.). Hygiene is an important aspect of habitability because filth facilitates bacterial growth and can cause skin irritations, noxious odors, and food contamination that lead to crew member infection and disease. In addition, social norms aboard the spacecraft will require each crew member to maintain an acceptable appearance.

Personal Hygiene

Body cleansing can be classified as superficial bathing and whole body bathing. Superficial bathing should be accomplished through the use of closed lavatories that provide hot and cold water. The hands are inserted into the lavatory through rubber diaphragms that act as water barriers to prevent water droplets from escaping into the spacecraft atmosphere when crew members wash their hands. An air suction device should be incorporated to carry water droplets to a drain. A weak soap containing a bacteriostatic or bacteriocidal agent should be available from either a squeeze tube or a squeeze bottle. A wetted sponge included with this system could be withdrawn from the lavatory to wash other portions of the body, including the head and face. Superficial bathing will minimize the need for whole body bathing. Additional superficial cleaning of the face and hands could be accomplished by chemical wipes. A supply of these wipes could be made available in the wardroom for use with meals and in the sleeping compartments to handle special occassion cleansing.

Social norms and natural habits have led to a psychological need for washing the entire body, e.g., showering. Several methods have been recommended for bathing. One of the early concepts incorporated the use of a soft bath suit. The soft bath suit was designed to fit the neck of the user and required the addition of several liters of water and a soap tablet. Washing was accomplished by rubbing the suit over all parts of the body. The suit was drained and then rinsed with several liters of water. When doffing the suit, a second man was required to assist in drying the bather and the suit. Privacy needs of the individual crew member, lack of comfort, and the use of another person obviate the use of this type of bathing.

Technological advances now make possible the use of a more conventional shower. Two shower types that are based on the same concept and use multiple shower heads to direct a fine spray over the entire body have been recommended. Liquid soap or detergent is included in the spray system and is controlled by the user. Water and soap is sprayed in a fine mist for removing dirt. Water spray alone is then actuated to rinse and carry away the soap and dirt.

Water is carried to the drain by a constant downdraft of forced warm air that also provides a drying action. The two shower types differ in that one has a hard cabinet that encloses the entire body and the other covers the body only to the neck, which causes head and hair cleansing difficulties. The cabinet that covers the entire body is preferred because better total body cleansing including the head can be accomplished. Body drying can be accomplished by the warm air downdraft. At least three showers will be needed for a crew of twelve men.

Clean Clothing

An integral part of general hygiene is the need for clean clothing. Clean outer garments should be available for change approximately once every three days and at least once every week. Clean undergarments may be needed for daily changes and at least one change every three days. To provide adequate clean clothing, a tumbler washer and dryer or equivalent device must be provided in the hygiene area.

Oral Hygiene

Oral hygiene is required during long-duration spaceflight to reduce tooth decay and bacterial growth in the mouth and throat. Oral hygiene also reduces obnoxious breath odors and helps maintain crew member morale. Normally, teeth should be cleaned after each meal but at a minimum of twice a day--after rising from sleep and just prior to sleep. Teeth cleansing should be a closed mouth operation to reduce atmospheric contamination from droplets. A brush and ingestible dentifrice/mouthwash represent the minimum requirement. Techniques for cleansing the brush after use can be developed in conjunction with lavatory facility training.

Shaving (Depilation)

Hygiene does not require removal of face hair; however, since the presence of copious amounts of hair on the face (1) increases bacterial growth, (2) makes cleansing more difficult, (3) is not conducive to space suit wear, and (4) presents a potential fire hazard, particularly in an oxygen enriched environment, shaving is recommended. Two shaving techniques available are (1) the use of lather from a tube and a safety razor, and (2) a mechanical or electric shaver fitted with a vacuum to pick up the cut hair. The second technique is the easiest and most acceptable for this purpose. Shaving will probably occur on a daily basis, but may occur at 3-day intervals.

Hair Cutting

Scalp hair protects the scalp and enhances head features. Many potential problems would be minimized if scalp hair is kept very short (approximately 1/4 in. in length). This could be accomplished by each crew member using a separate cutting head with his shaver. However, social norms and personal preferences lead to requirements for hair styling and/or individuation of hair appearance. To accomplish this, two crew members should be trained to trim hair. A face shaver with a special cutting head could be used for this purpose.

Nail Care

Fingernails should be cut and cleaned using the lavatory because particulate matter can be carried away by the air downdraft and/or waterflow. Toenails should be cut in the shower stall to minimize debris. Nails should be cut every one to three weeks. Standard mechanical nail clippers can be used--one for each crew member and one spare. Nails can be cleaned with the cleaning point on the clippers.

Waste Management

The habitability aspects of waste management deal with the problems of man's interface with the system. The techniques of handling the wastes after they are eliminated from the individual's body are not pertinent to this discussion as long as the system does not impose new problems for the users, e.g., odor. However, the system selected must collect and isolate all body waste (specifically, urine, semen, feces, vomitus, mucous, hair, nails and food residue). The system also must collect and isolate personal hygiene waste materials, food packaging materials, and wash and laundry water.

The latrine facility will be used for collection of feces and urine, and should be aesthetically acceptable, easy to use, and representative of latrines used on earth (i.e., there should be no special direct contact techniques such as condoms, elastic, or adhesive devices required between the man and the system). Cleaning of the body surfaces following defecation should be accomplished easily.

The waste management area/system must prevent odors from escaping and the buildup of microorganisms. To meet this requirement, the latrine area must be physically isolated from other living quarters and capable of isolating odors, gases, and aerosols. Odors following latrine use must be removed within approximately five minutes. The surfaces of the latrine area must be cleaned and disinfected easily to provide microoganism control.

Ancillary collection devices for hair, nails, food residue, and packaging materials must be available, easy to use, easy to clean, and not cause any odor or hygienic problems from their use. Clippers with a suction source and debris trap can trap hair and fingernail materials. A system for collection of food residue, food packaging material, and hygiene aid containers and equipment must be provided.

Waste Management and Hygiene Compartments

Water control is most critical in the waste management and hygiene compartments. It is anticipated that the following functions will take place in the personal hygiene compartment:

(1) Full body washing

(2) Hands and face washing

(3) Shaving

(4) Oral hygiene (with digestible dentifrice)

(5) Clothes washing and drying

(6) Hair and nail trimming

In the waste management compartment, the following functions will take place:

(1) Fecal elimination

(2) Urination

(3) Disposal of vomitus

Assuming that compartment use will be similar to earth procedure, it is anticipated that the majority of the crew will converge at these compartments in the morning prior to or immediately following breakfast. Therefore, these spaces must be designed to accommodate the major part of the crew during the same time period. Of importance is the smooth flow of personnel through the functions listed above with the least amount of queuing within the space limitations and the number of various fixtures and pieces of equipment involved.

VOLUME CONSIDERATIONS

Hygiene Room Volume Requirement

Volume considerations are predicated on the number of personnel being serviced and the reliability of the equipment being utilized. Baseline considerations are those necessary to support twelve crewmen for normal mission requirements with a crew of twenty-four during crew changeover periods. Data pertaining to frequency of defecation and urination per person per day have been collected previously, and this information has been correlated with the understanding that one-unit-may-fail predicts the required number of toilets, showers, and sinks. At least one full-length mirror should be provided due to

the psychological desirability of maintaining "body image" in a low somesthetic environment. Table 8-1 lists the equipment required for the hygiene room.

TABLE 8-1

HYGIENE EQUIPMENT TABLE

Item No.	Description	No. Required
1	Toilets	3
2	Showers	3
3	Wash Basins	3
4	Mirror (Full Length)	1
5	Washers and Dryers	1 each

The areas required for the hygiene equipment and 95th percentile personnel are listed in Table 8-2.

TABLE 8-2

AREA REQUIREMENTS

Equipment	Area Required
Toilets	4 ft by 2 ft 9 in.
Showers	3 ft by 3 ft
Wash basins	2 ft 6 in. by 1 ft 6 in.
Aisle	3 ft 6 in. wide for 2 men passing side by side 1 ft 6 in. wide for 1 man aisle
Washers and dryers	3 ft by 2 ft 6 in.

The area required for the hygiene room, based on fig. 8-1, is as follows:

3 Toilets	(2 ft 9 in.) (3)	=	8.00 ft	Length
3 Showers			9.00 ft	
			17.25 ft	= 17 ft 3 in.
1 Toilet		=	4.00 ft	Width
			3.50 ft	
			3.00 ft	
			10.50 ft	= 10 ft 6 in.

If a pie-shape structure is used (fig. 8-2), the dimensions can be calculated as below. The width of 10 ft 6 in. is not available, and the width will be varied accordingly.

$$\text{Required Area} = (17.25 \text{ ft})\ (10.50 \text{ ft}) = 181.13 \text{ ft}^2$$

$$A_L = \pi v_L^2 = (3.14)\ (15 \text{ ft})^2 = 706.50 \text{ ft}^2$$

$$A_s = \pi v_s^2 = (3.14)\ (5 \text{ ft})^2 \doteq \underline{77.50 \text{ ft}^2}$$

$$629.00 \text{ ft}^2$$

$$\left(\frac{X}{360}\right) (629) = 181.13 \text{ ft}^2 \text{ hygiene area}$$

$$X = \frac{(181.13)\ (360)}{(629)} = \approx 104 \text{ deg}$$

are length calculations for wall space.

$$C_{ULL}{}^1 = \left(\frac{104}{360}\right) (2\pi)\ (15) \approx 27 \text{ ft } 4 \text{ in.}$$

$$C_{ULS}{}^2 = \left(\frac{104}{360}\right) (2\pi)\ (5.0) \approx 9 \text{ ft. } 1 \text{ in}$$

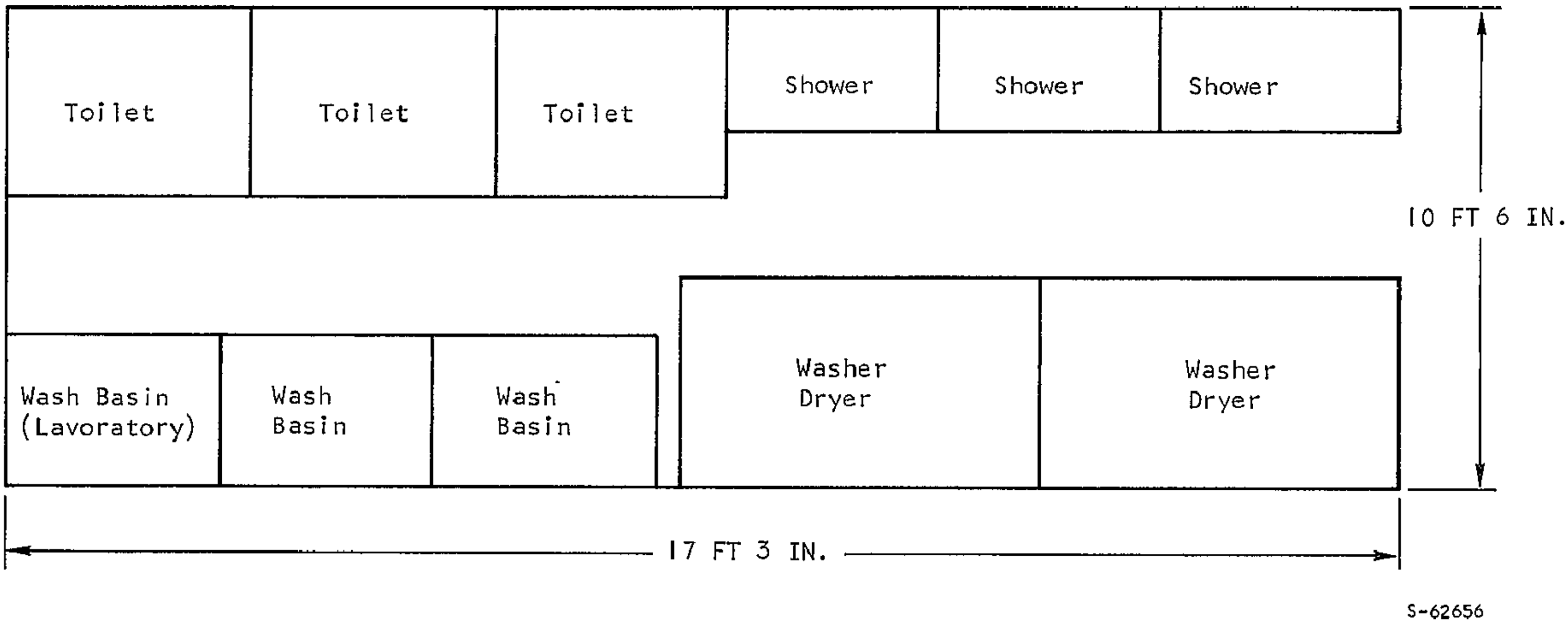


Figure 8-1. Hygiene Room Area Requirements

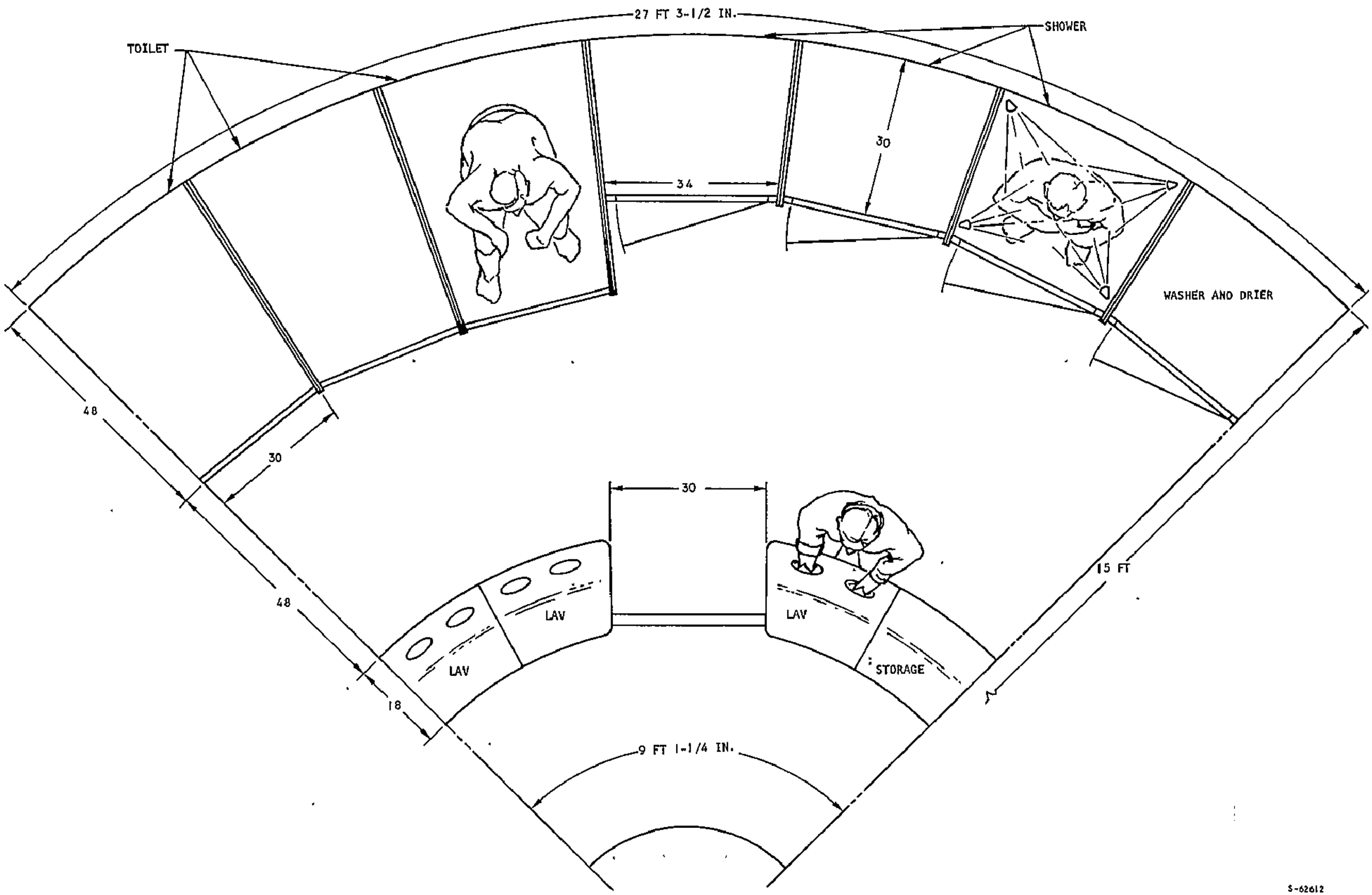


Figure 8-2. Pie-Shape Structure for Hygiene Area

TRAFFIC FLOW STUDY

Traffic flow in the hygiene area was investigated for Plans A and B as shown in figs. 8-3 and 8-4. Usage rates and traffic patterns to each of the hardware components were estimated and shown graphically, and this graphical presentation was used to determine travel distances, congestion, and collision points. Preliminary layouts show the entrance on the left and an estimated daily travel distance of 1409 ft for Plan A and 1276 ft for Plan B. An annual saving of 48,545 ft of travel is gained by the arrangement in Plan B. The most promising layouts were placed on the gridded floor for full-scale evaluation (fig. 8-5). In fig. 8-5a, the preferred rectangular layout is shown with the entrance on the left. In fig. 8-5b, a rectangular plan is shown with the entrance centrally located on a side. This arrangement is easily adapted to the wedge shape dictated by the circular floor plans of the spacecraft. Benefits of this plan are the short travel distance and the placement of the high usage lavatories close to the entrance for easy access. Distance travelled during a typical day's use is 1145 ft; this travel distance is less than that required by the other arrangements. A layout of this arrangement is shown in fig. 8-2. Use of the hygiene area is depicted in fig. 8-6.

WASTE MANAGEMENT AND PERSONAL HYGIENE COMPARTMENT

The personal hygiene compartment is a sealed negative pressure compartment containing showers, toilets, lavatory, and clothes washer and dryer. Due to the anticipated use rates of waste management and personal hygiene equipment, these two functions require separate compartments. A crew size of 12 will necessitate two toilets and two personal hygiene compartments. An additional toilet and shower (making a total of three each) is recommended. These will greatly reduce queuing and provide backup in case one of the others malfunctions. The toilets will provide for defecation, urination, and waste disposal. The personal hygiene compartment will provide for bathing, washing with liquids, personal grooming, oral hygiene, clothes washing and clothes drying.

The zero-g shower (fig. 8-7) is an inner sealed compartment with multiple nozzles that spray a mist of water and soap and then water only to rinse. A blow-down capability carries moisture away from the user's head and provides warm air for drying. Conventional towels may be used if preferred. This compartment permits total body bathing, including the face and hair, and is recommended because of this advantage. The configuration shown in fig. 8-7 was found to be larger than necessary. The minimum recommended shower base size is 30 in. wide and 30 in. long.

An alternate solution (fig. 8-8) makes use of a compartment that is sealed at the neck to prevent water from gathering at the user's head. This constraint does not allow washing of face and hair while in the shower, which causes personnel to clean hair and face by other means (i.e., chemical wipes).

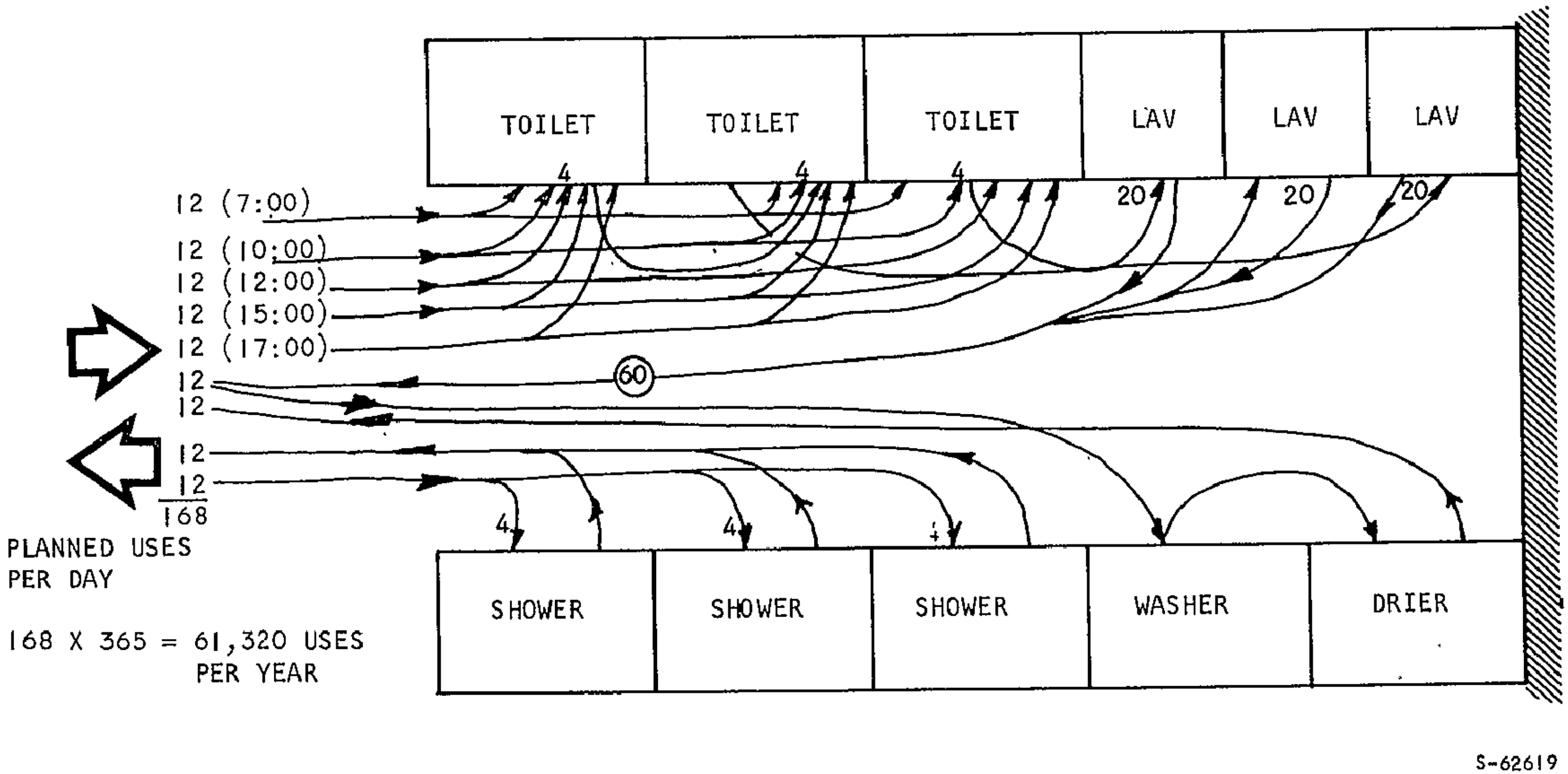


Figure 8-3. Traffic Flow in Hygiene Area, Concept A

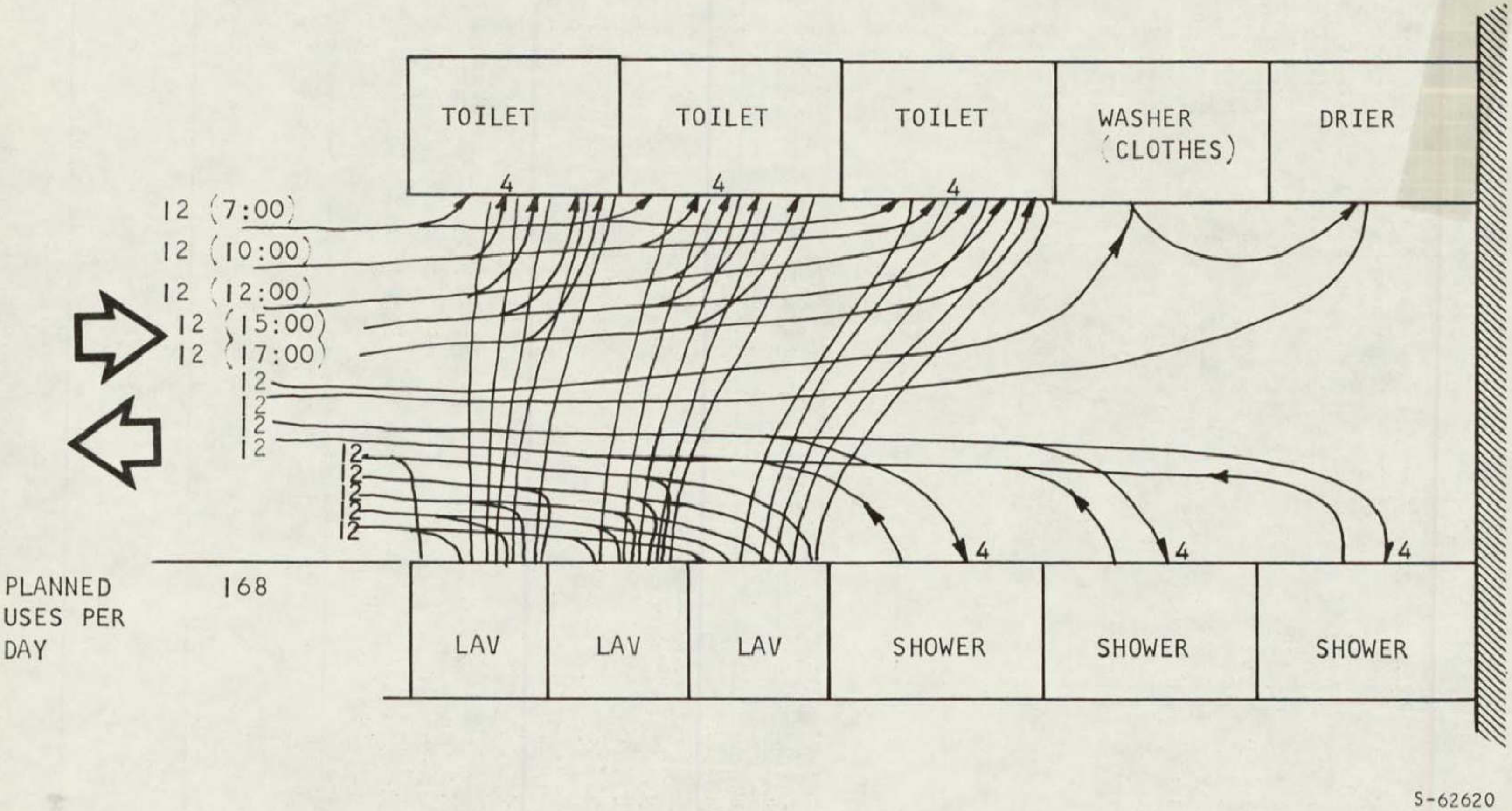
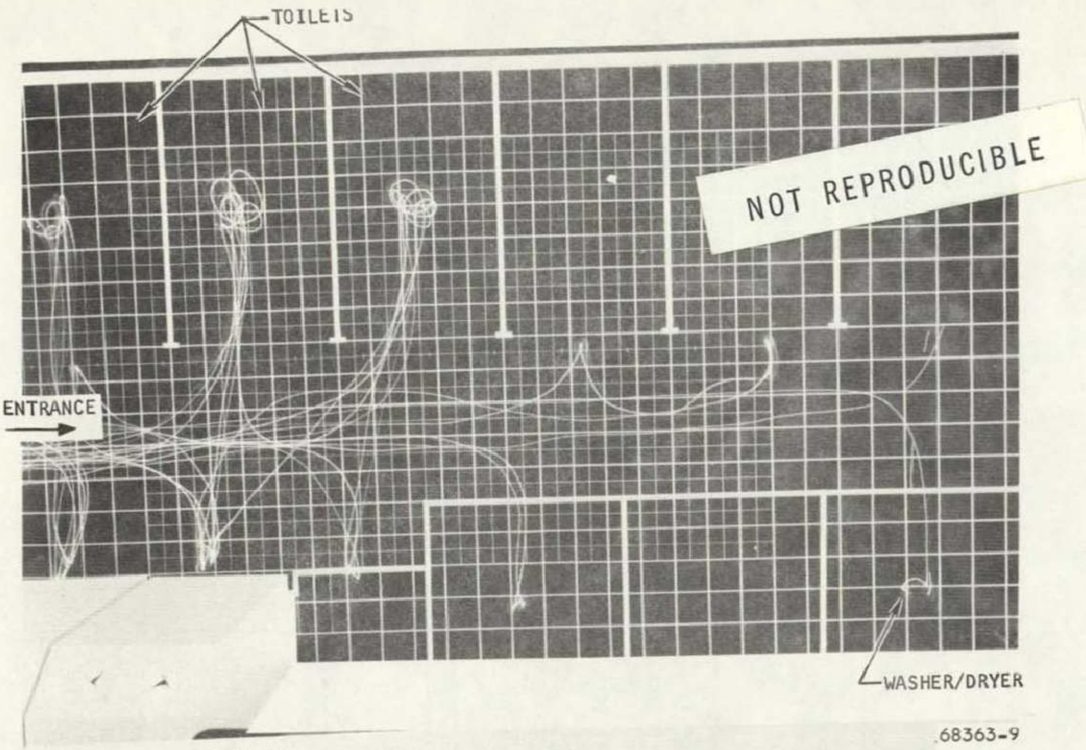
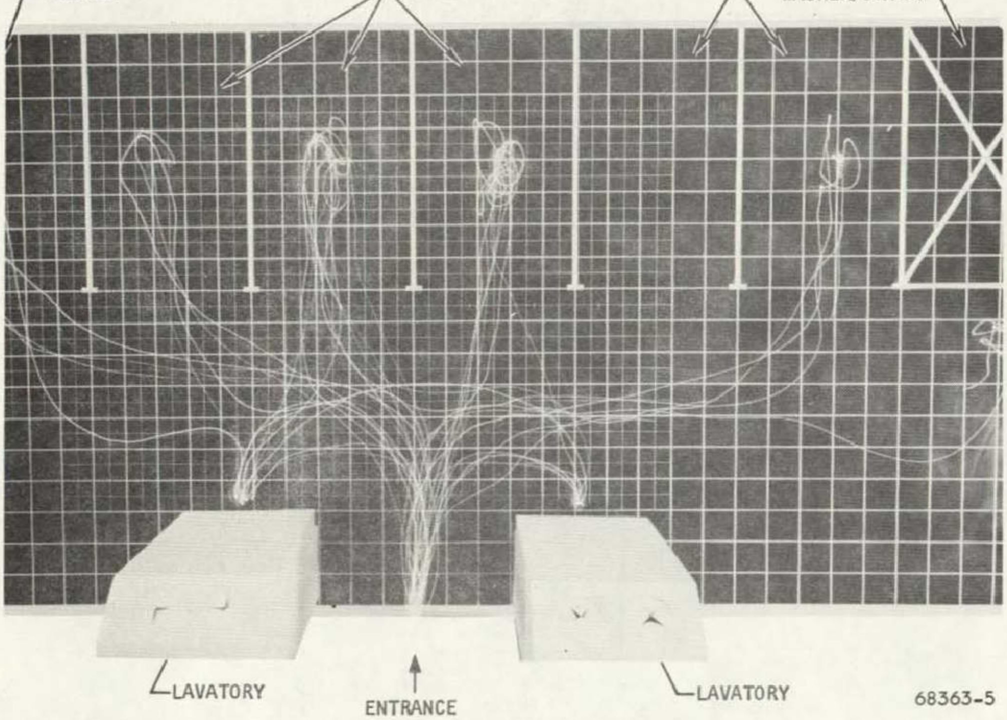


Figure 8-4. Traffic Flow in Hygiene Area, Concept B



a. TRAFFIC FLOW THROUGH HYGIENE AREA SHOWING FREQUENTLY USED ITEMS PLACED NEAR THE ENTRANCE ON THE LEFT



b. TRAFFIC FLOW THROUGH HYGIENE AREA SHOWING FREQUENTLY USED ITEMS NEAR CENTER ENTRANCE

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Figure 8-5. Full Scale Evaluation of Hygiene Area Traffic

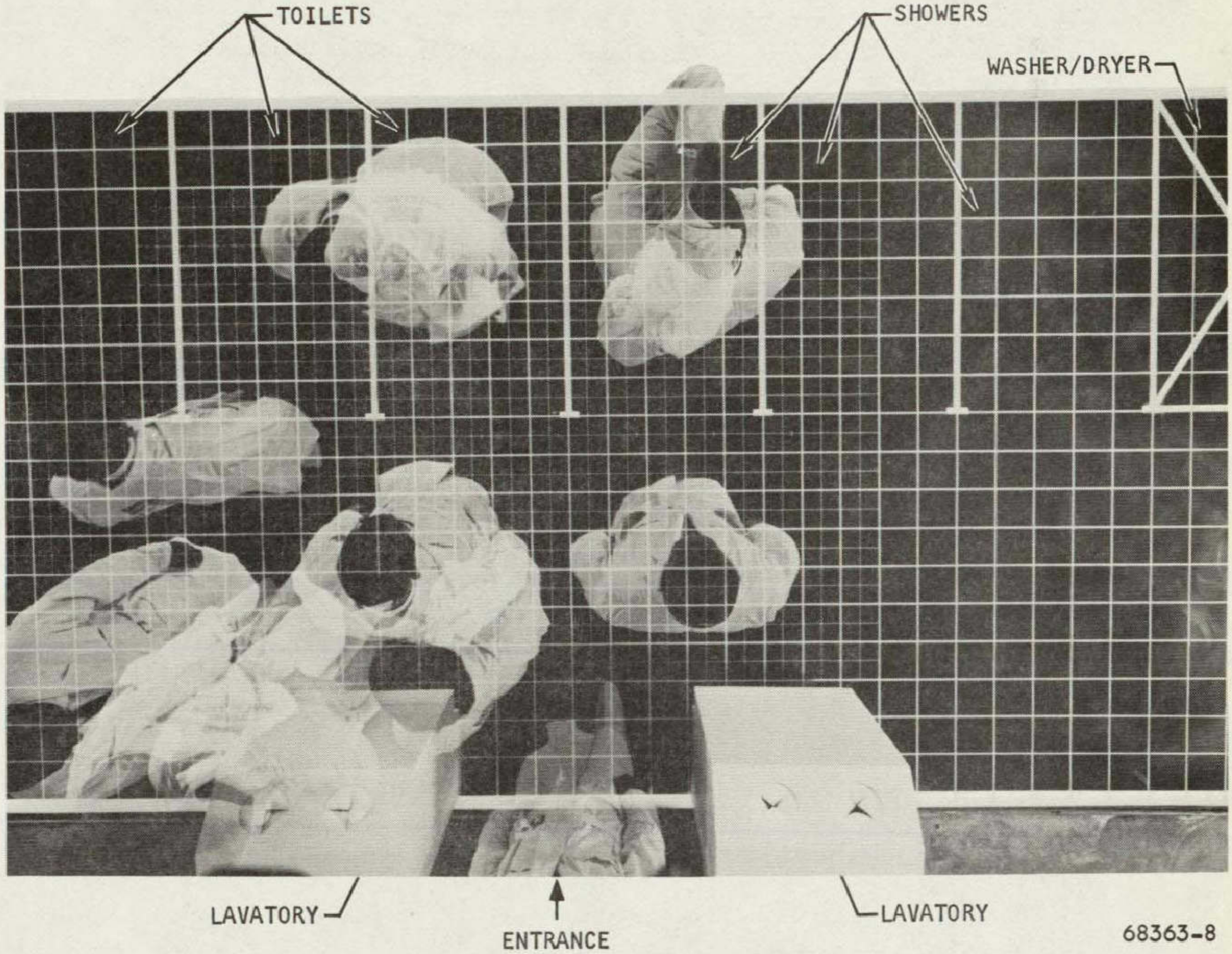


Figure 8-6. Hygiene Area in Use

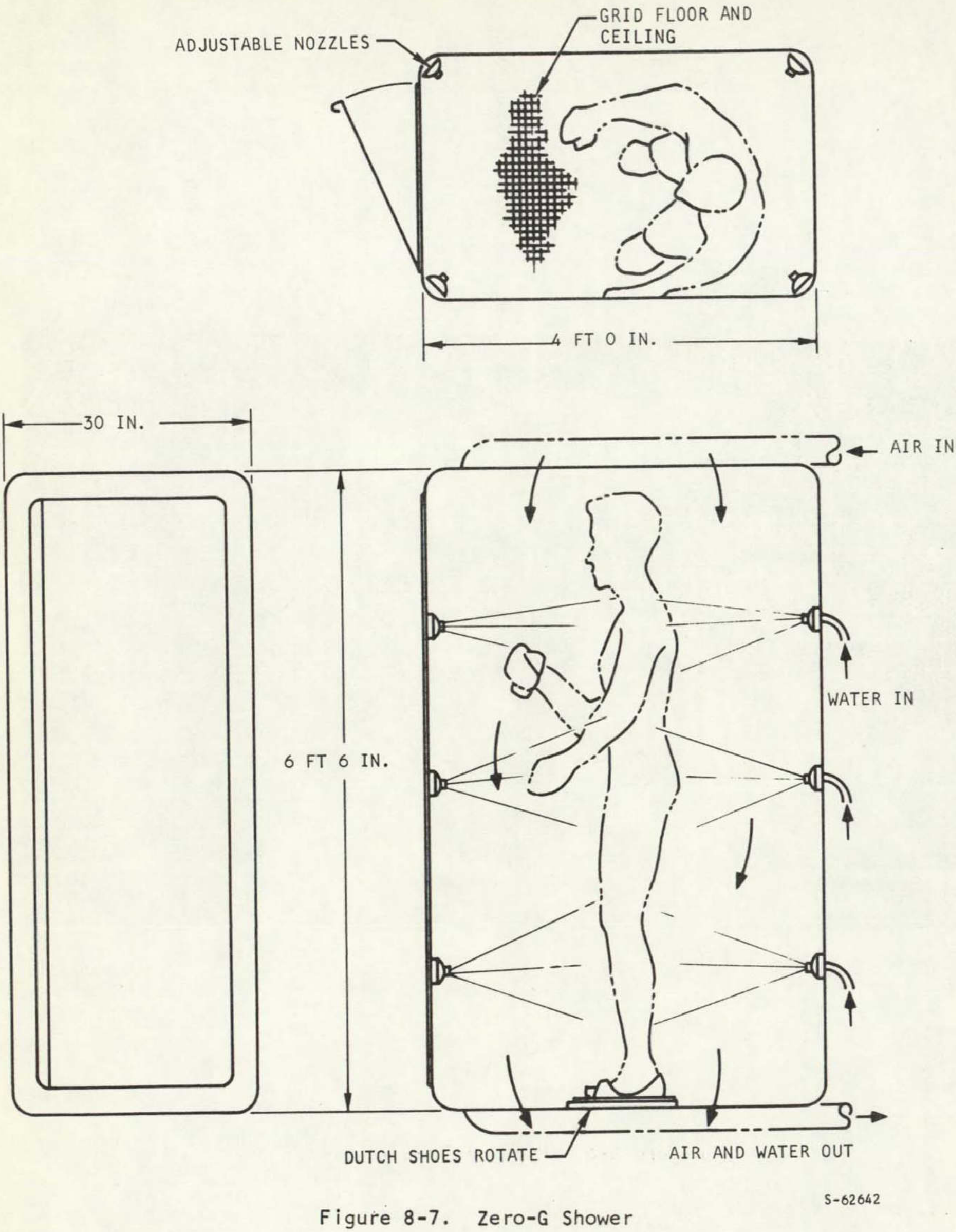


Figure 8-7. Zero-G Shower

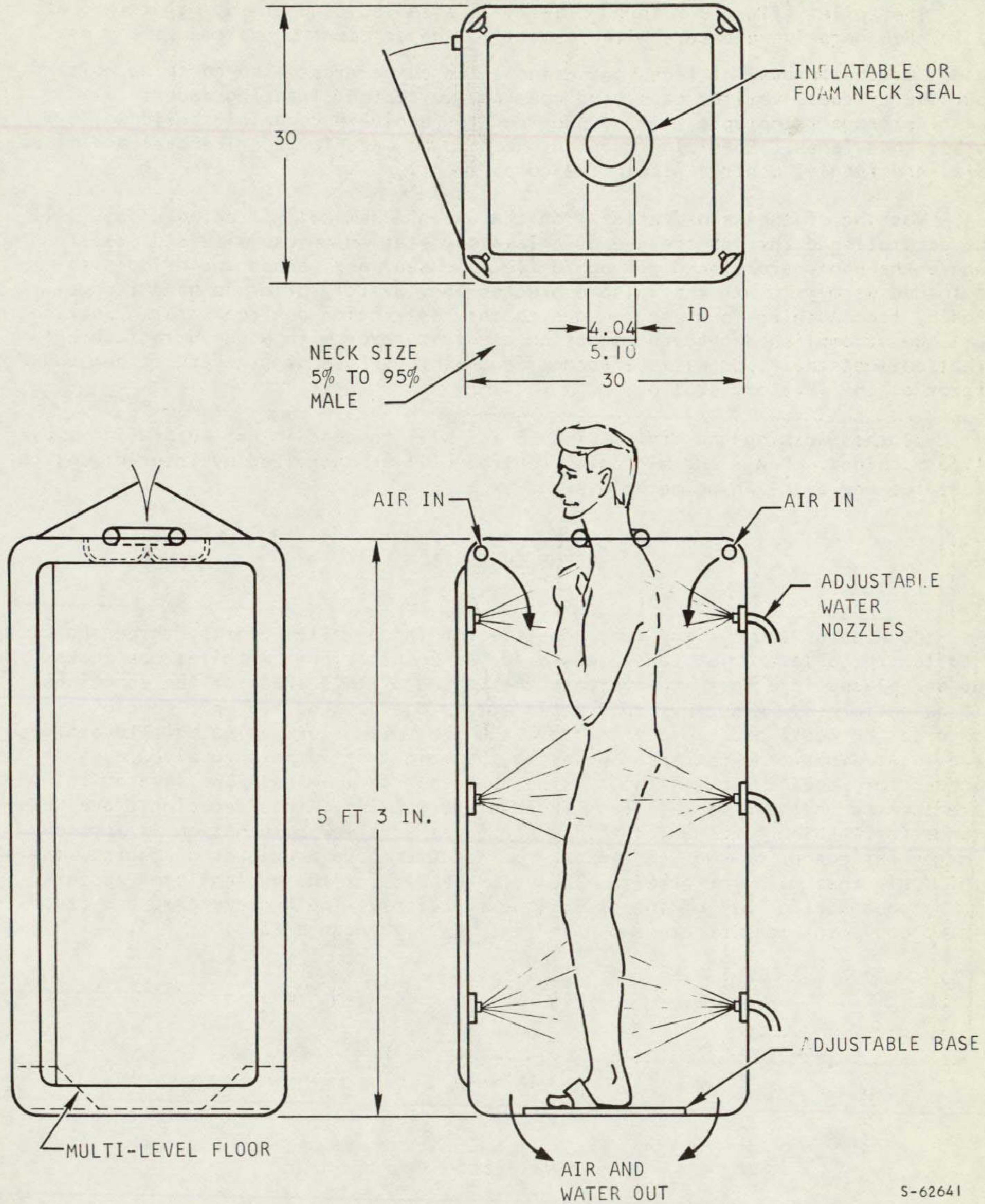


Figure 8-8. Zero-G Body Shower

The toilet (figs. 8-9 through 8-11) is a sealed compartment maintained at 1 in. H_2O negative pressure with respect to the adjacent compartments and is used for the removal of feces and urine. The compartment also contains multipurpose tissues, vomitus bags, and chemically treated cleansing papers. A waste storage receptacle will be provided to receive and contain solid waste other than feces. Special provisions need to be made for odor removal and microbial and fungial control within the compartment.

Washing of the hands, aside from the use of chemically treated wipes, will be accomplished through the use of a lavatory station (figs. 8-12 and 8-13) where the hands are placed through a flexible seal and washed and dried with a forced warm airflow that also evacuates the lavatory prior to hand removal. Again, face washing is a problem due to the restriction on free water. Shaving will be accomplished through use of an electric razor with a vacuum attachment that collects hair, or will be accomplished through use of standard lather and a razor at the lavatory station.

Clothes washing and drying (fig. 8-14) will be done in the automatic tumbler type machines. Fungi and microbial control will be exercised by interior design features and by cleaning materials.

MOCKUP EVALUATION

Mockups of the hygiene area consisted of three toilet booths, three shower stalls, three lavatories, and a washer/dryer combination. A toilet was mocked up and placed in a booth to evaluate the volume of this area for the functions to be performed. Also, a shower stall with a door was mocked up. People entered the stall and closed the door, and the volume was evaluated. Lavatories are located near the entrance and along the main traffic path to allow easy access for washing hands without using the other facilities. The lavatories are located on the exit path from the hygiene facility, thus reducing travel distance for washing hands after toilet use. Washer/dryer combination is located in the far corner on the least used area because there are fewer contacts with this unit than with the others. The volume shown for the hygiene area appears to be adequate for all of the prescribed functions. The hygiene area and associated equipment mockups are shown in figs. 8-15 through 8-23.

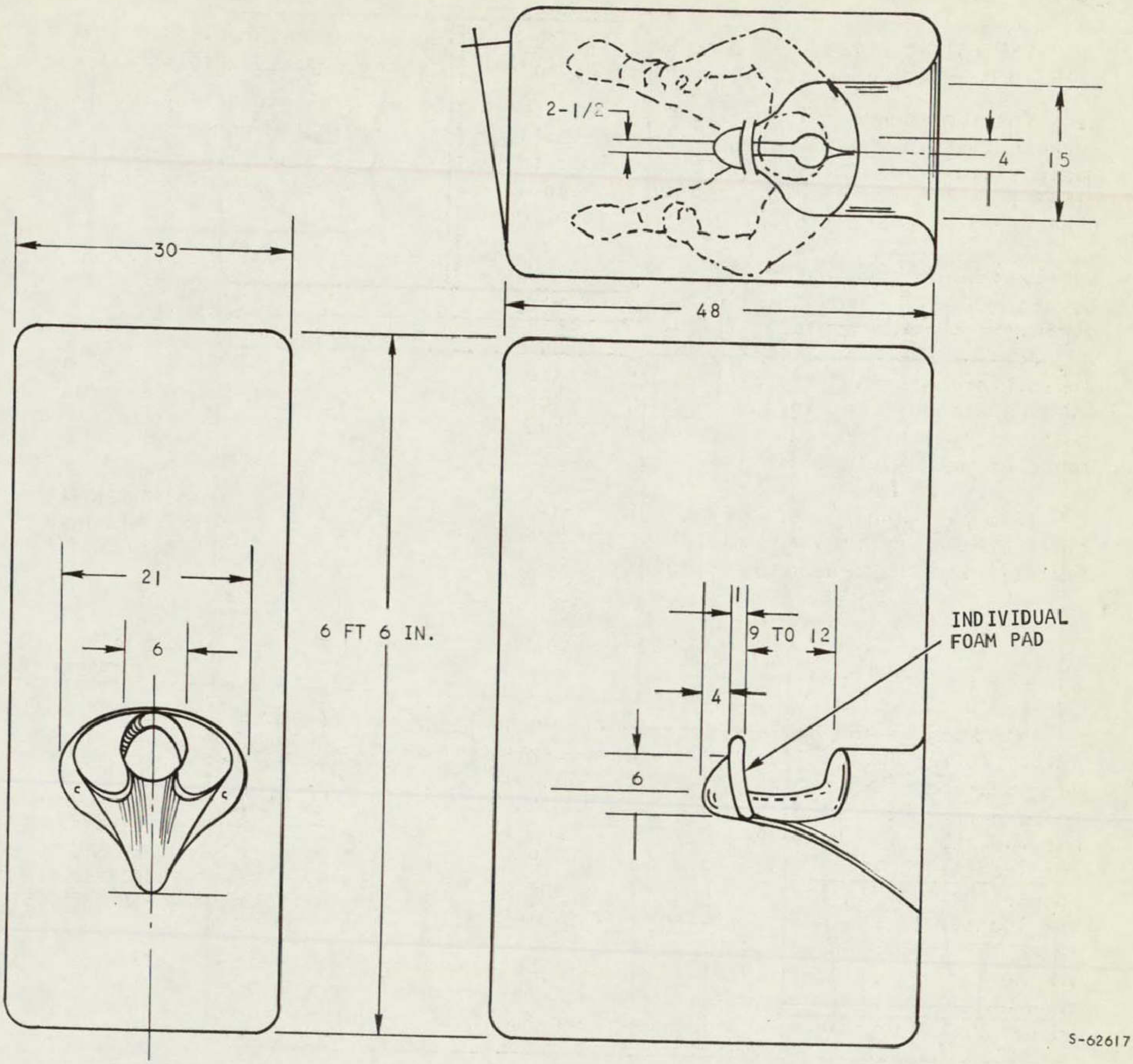


Figure 8-9. Zero-G Toilet

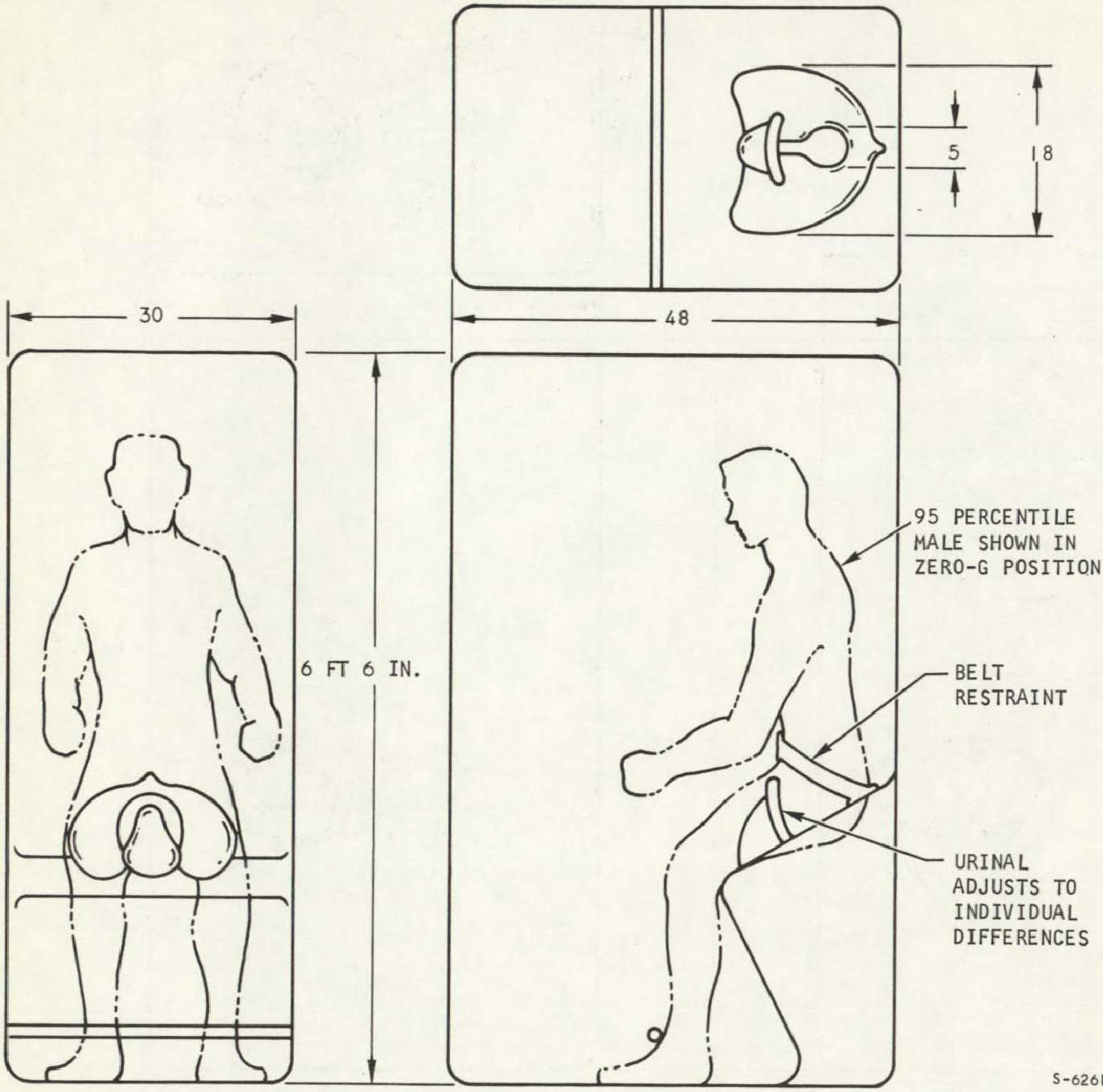


Figure 8-10. Zero-G Contoured Toilet

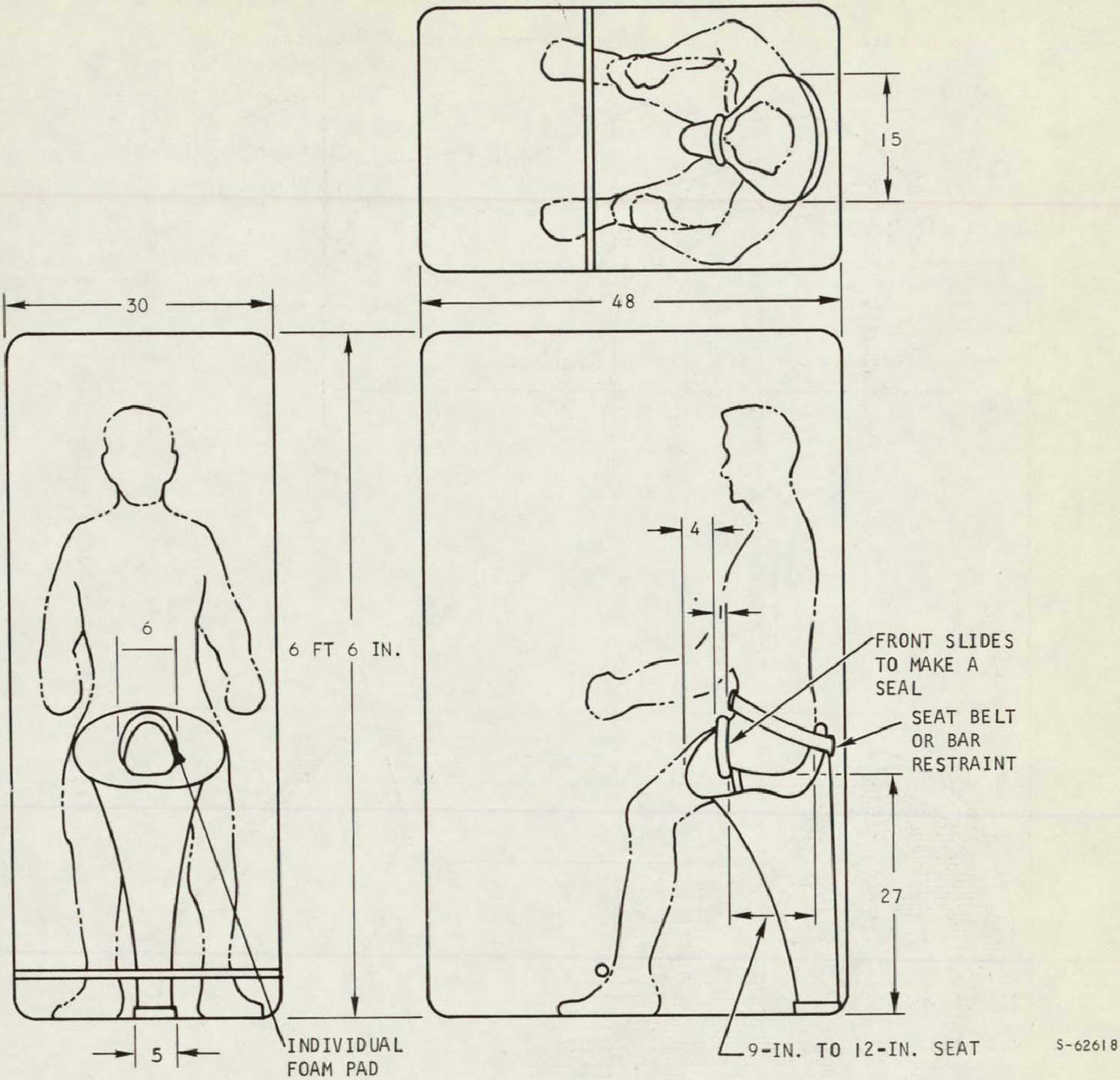


Figure 8-11. Zero-G Toilet in Use

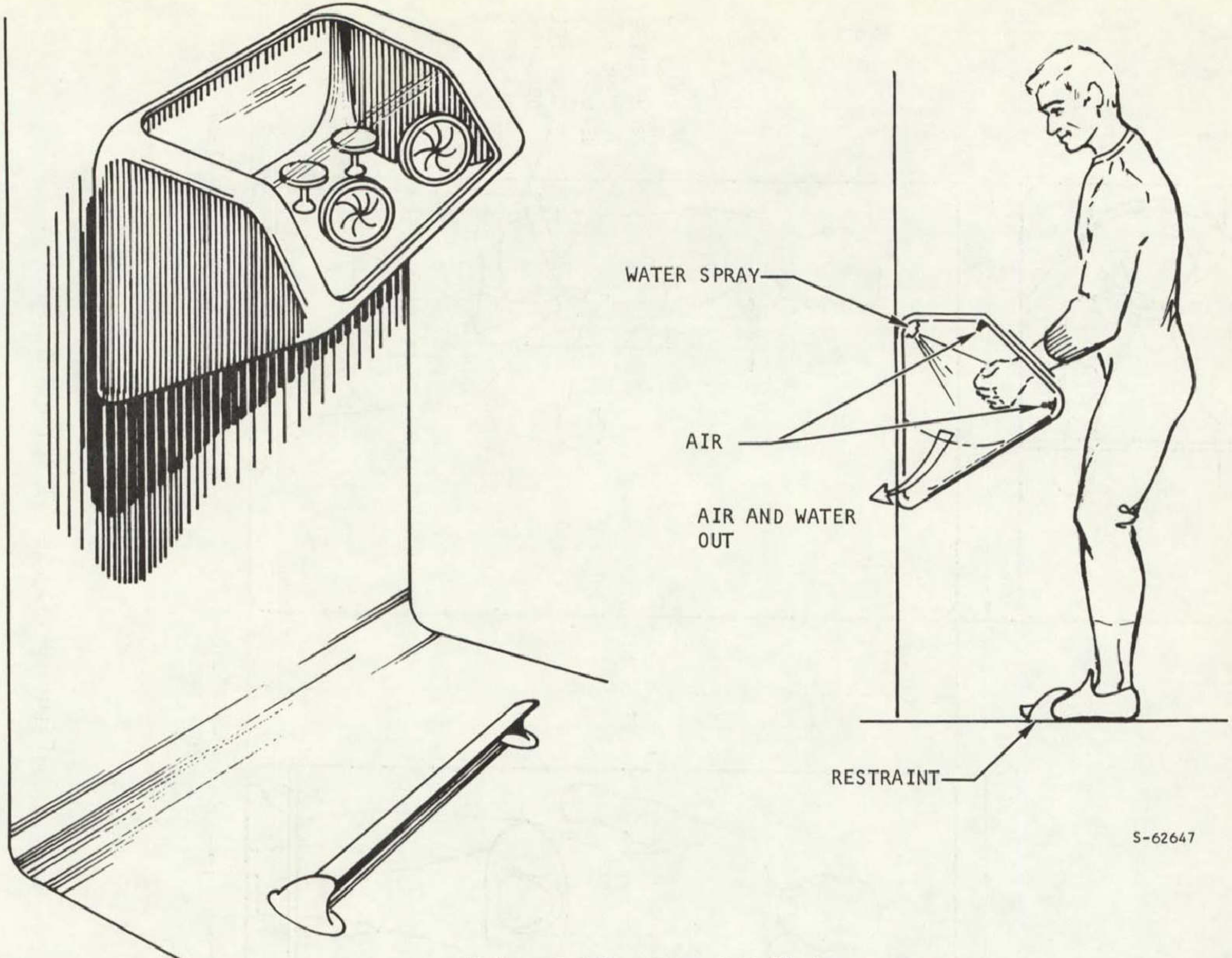


Figure 8-12. Zero-G Wall Lavatory

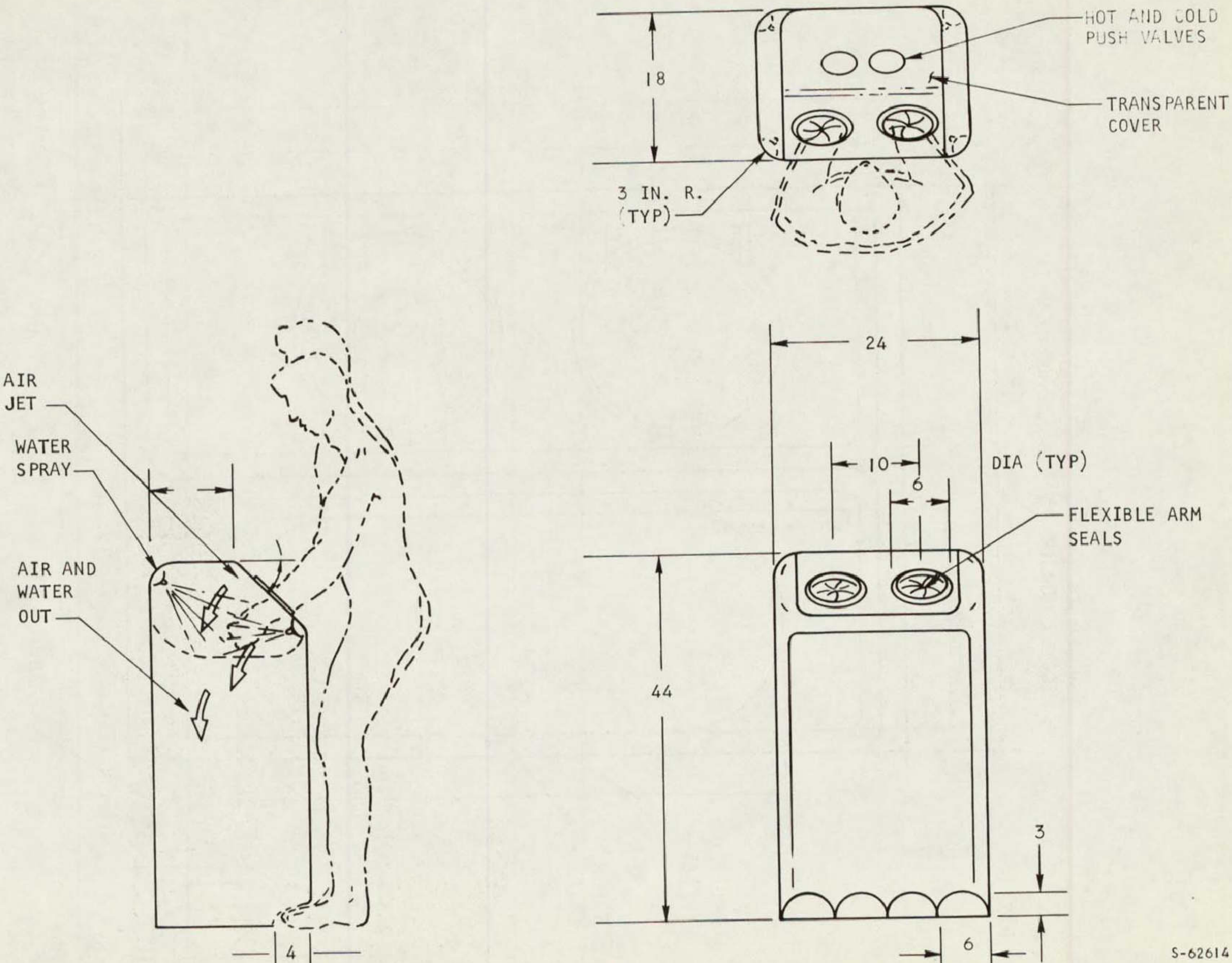


Figure 8-13. Zero-G Floor Lavatory

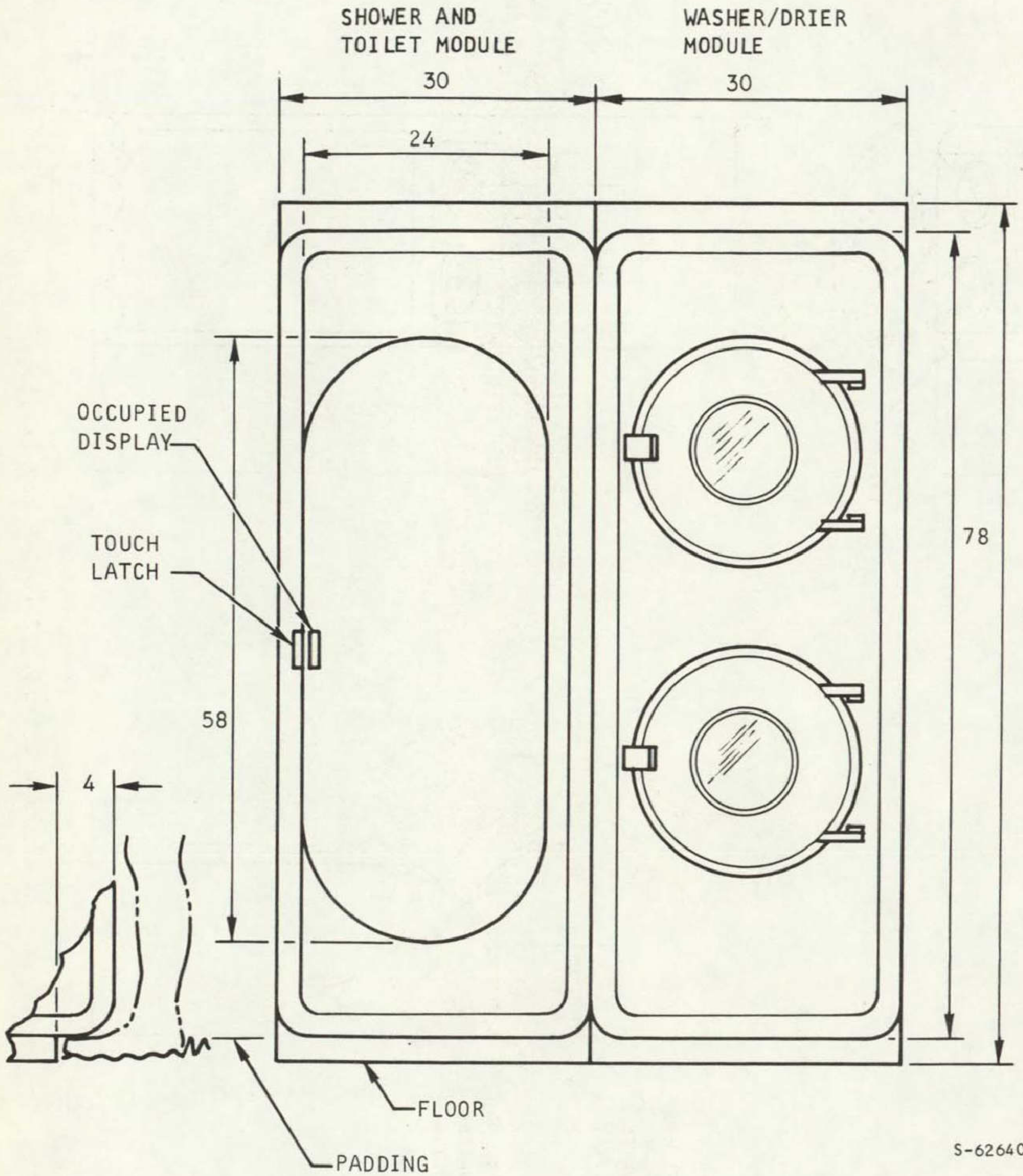


Figure 8-14. Typical Modular Construction Used in Hygiene Area

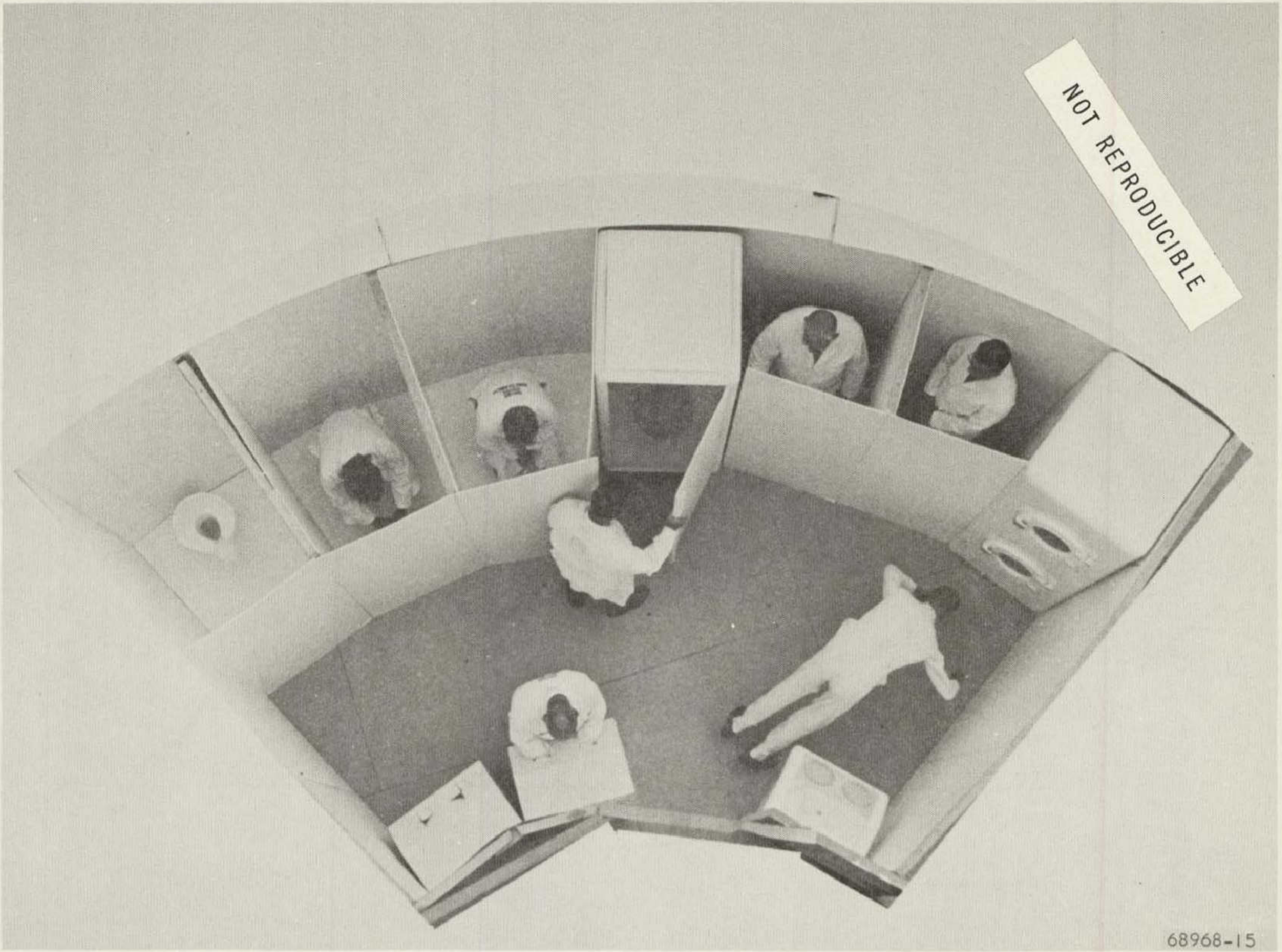


Figure 8-15. Hygiene Area Facilities in Use

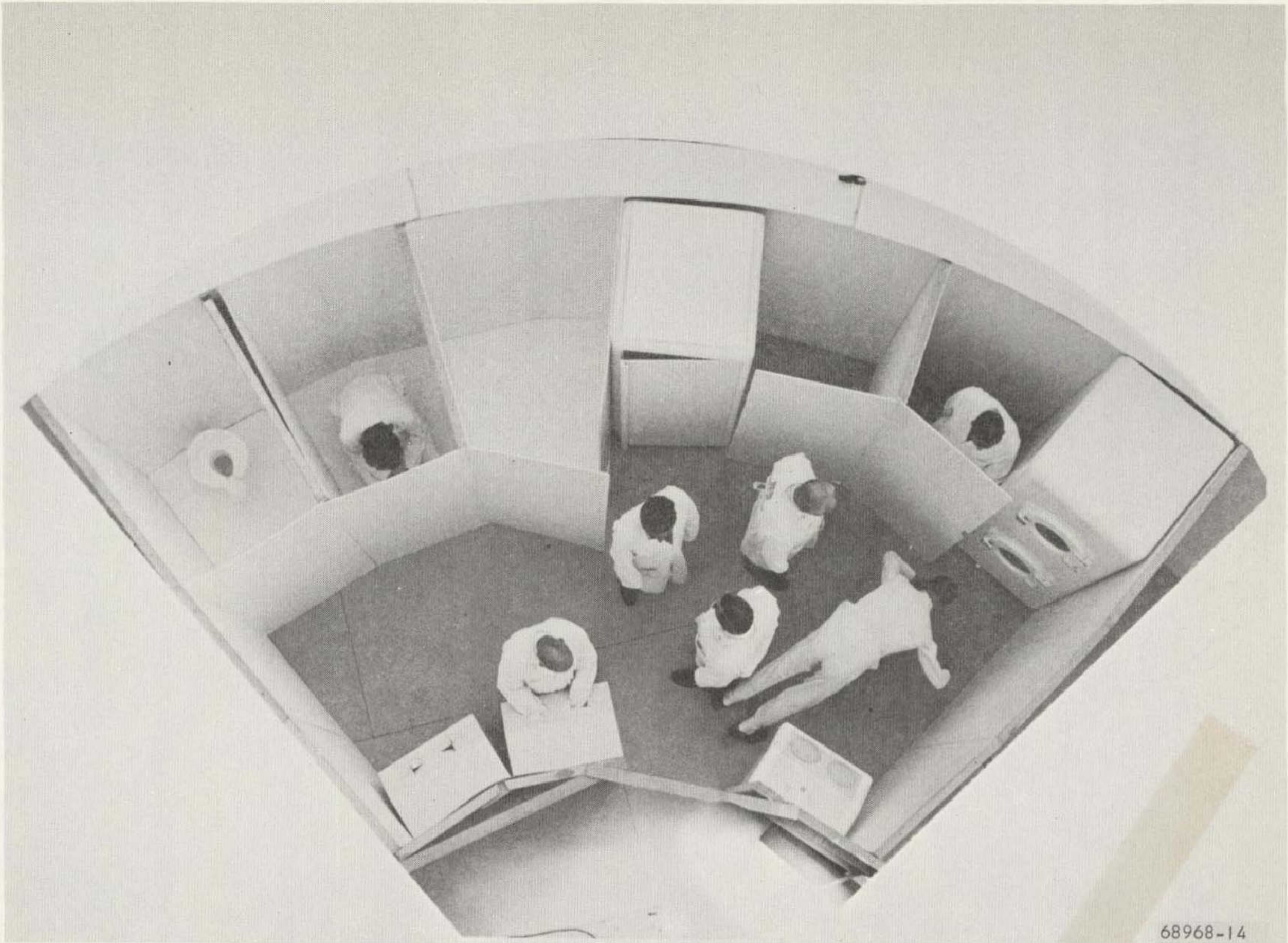


Figure 8-16. Adequate Volume of Hygiene Area for Crew Members

Figure 8-17. Zero-G Toilet

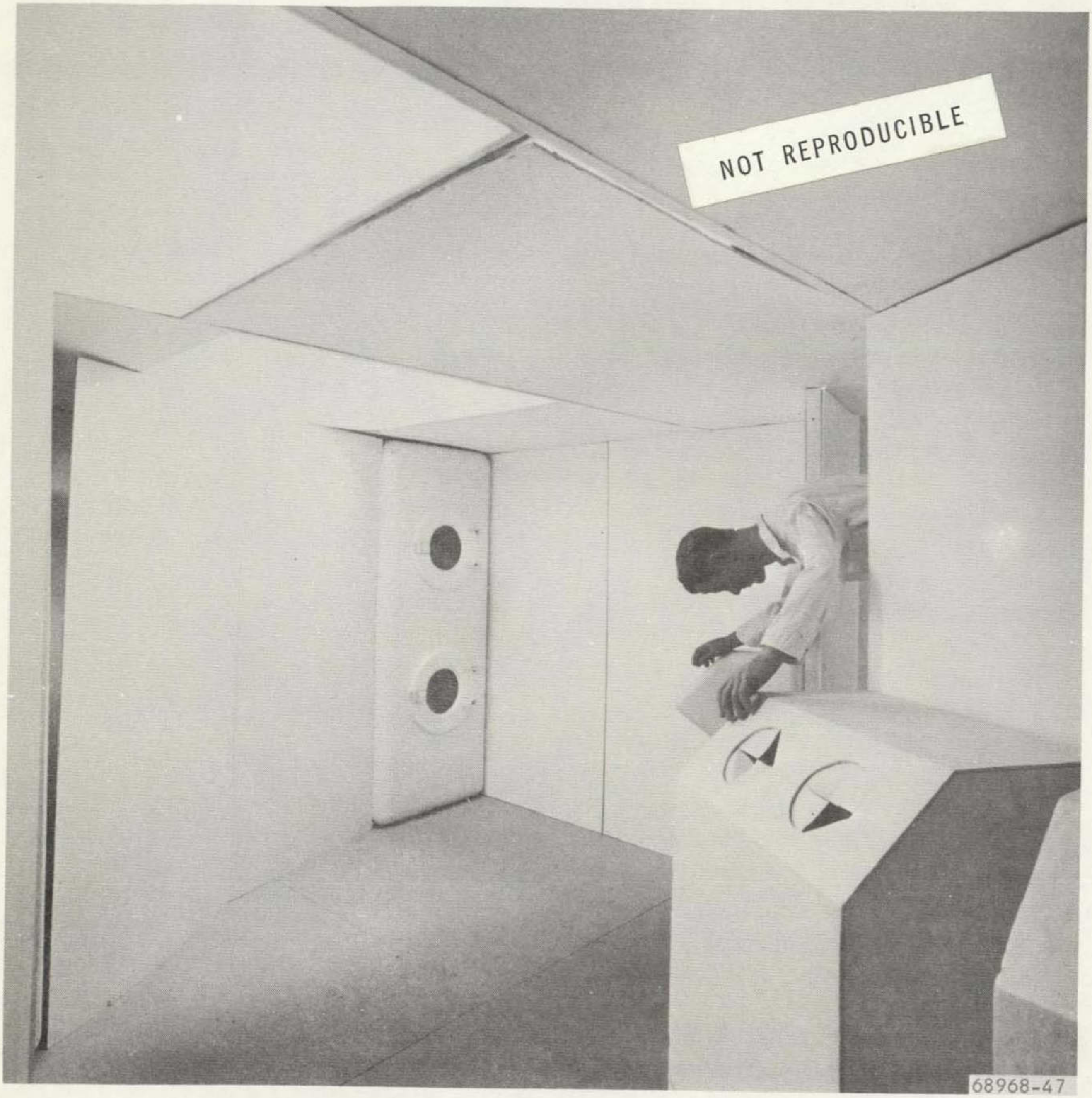


Figure 8-18. Subject Entering Toilet Area

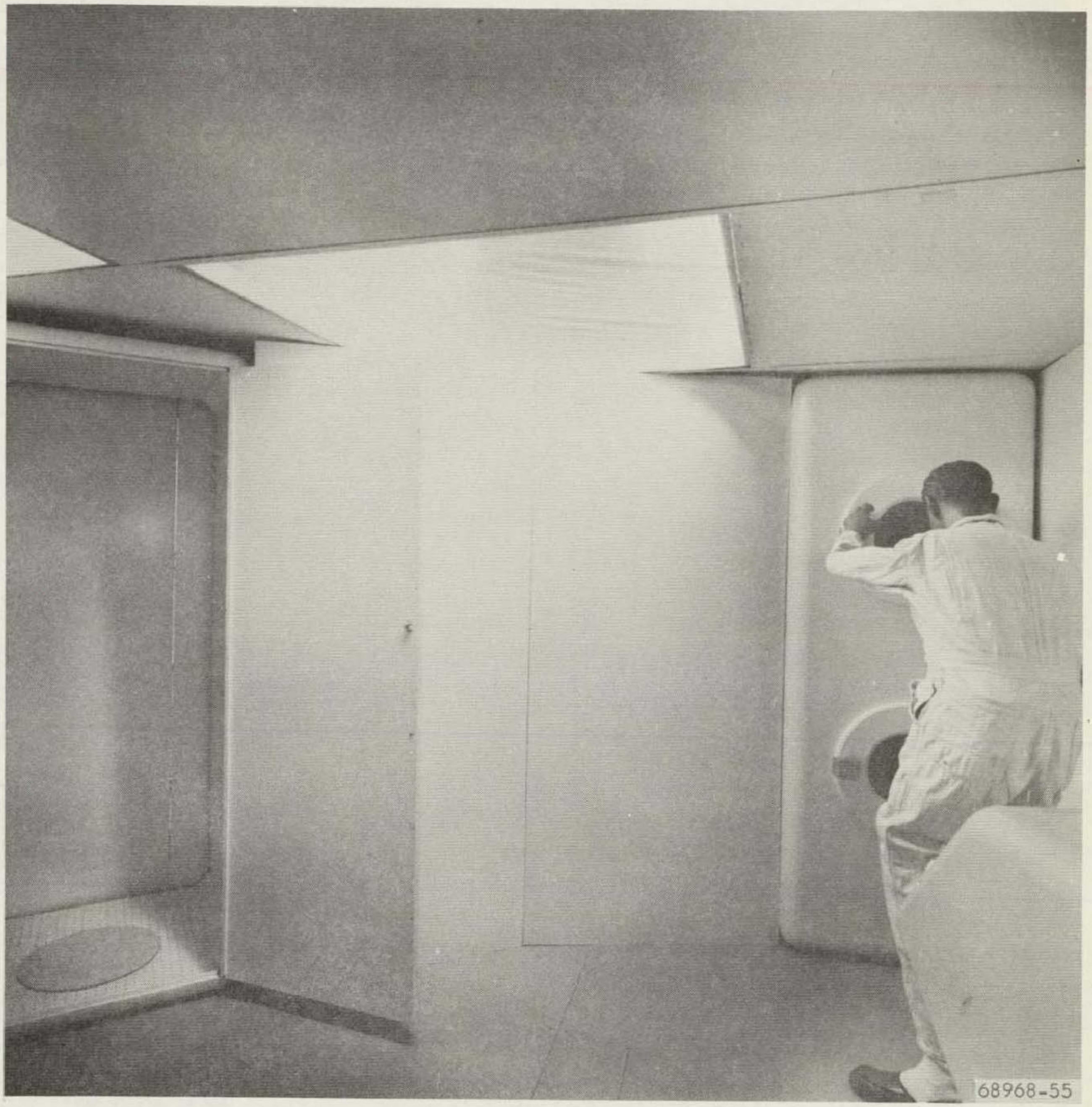


Figure 8-19. Subject Using Clothes Washer with Shower Shown at Left

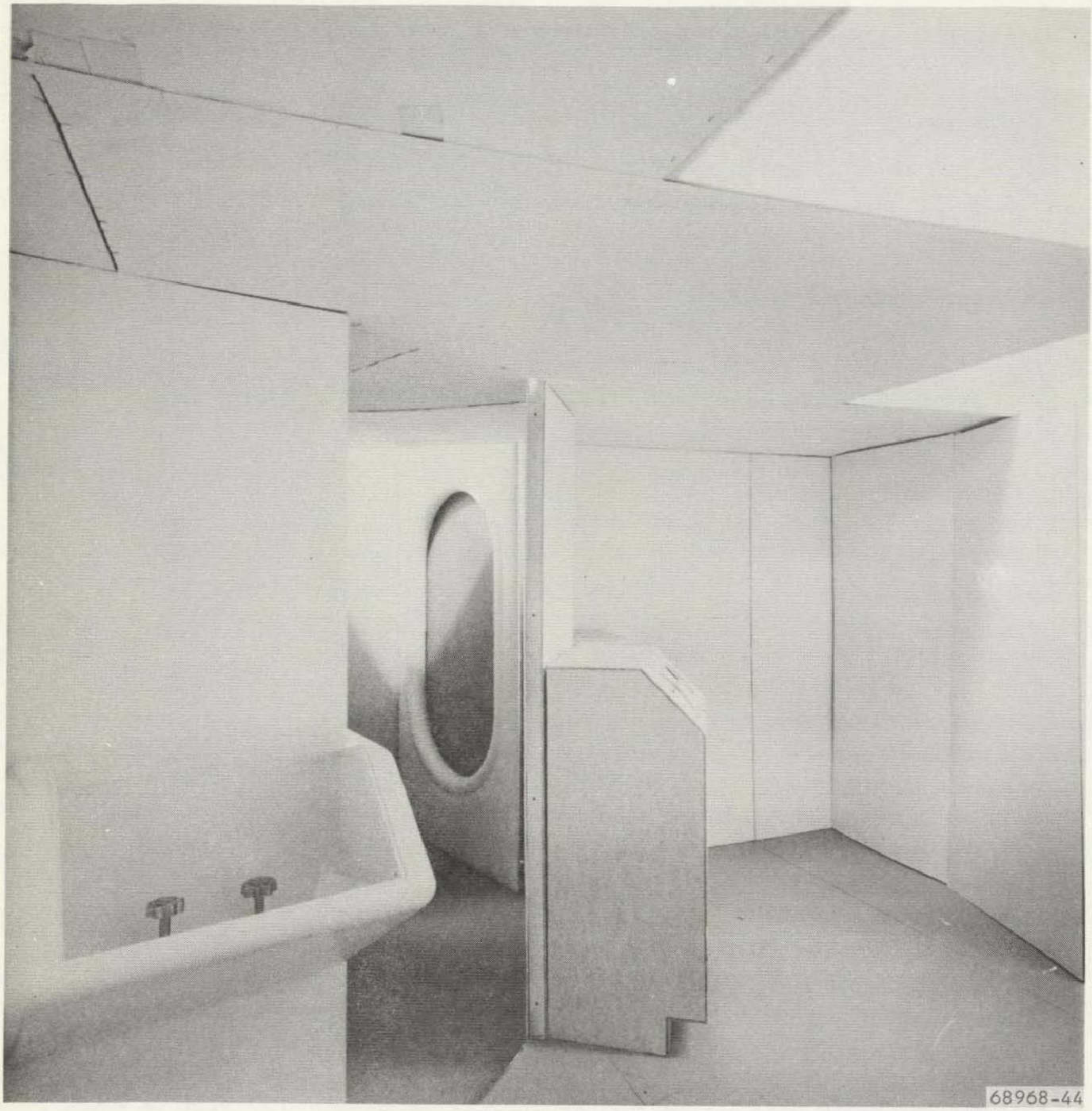


Figure 8-20. Zero-G Lavatory

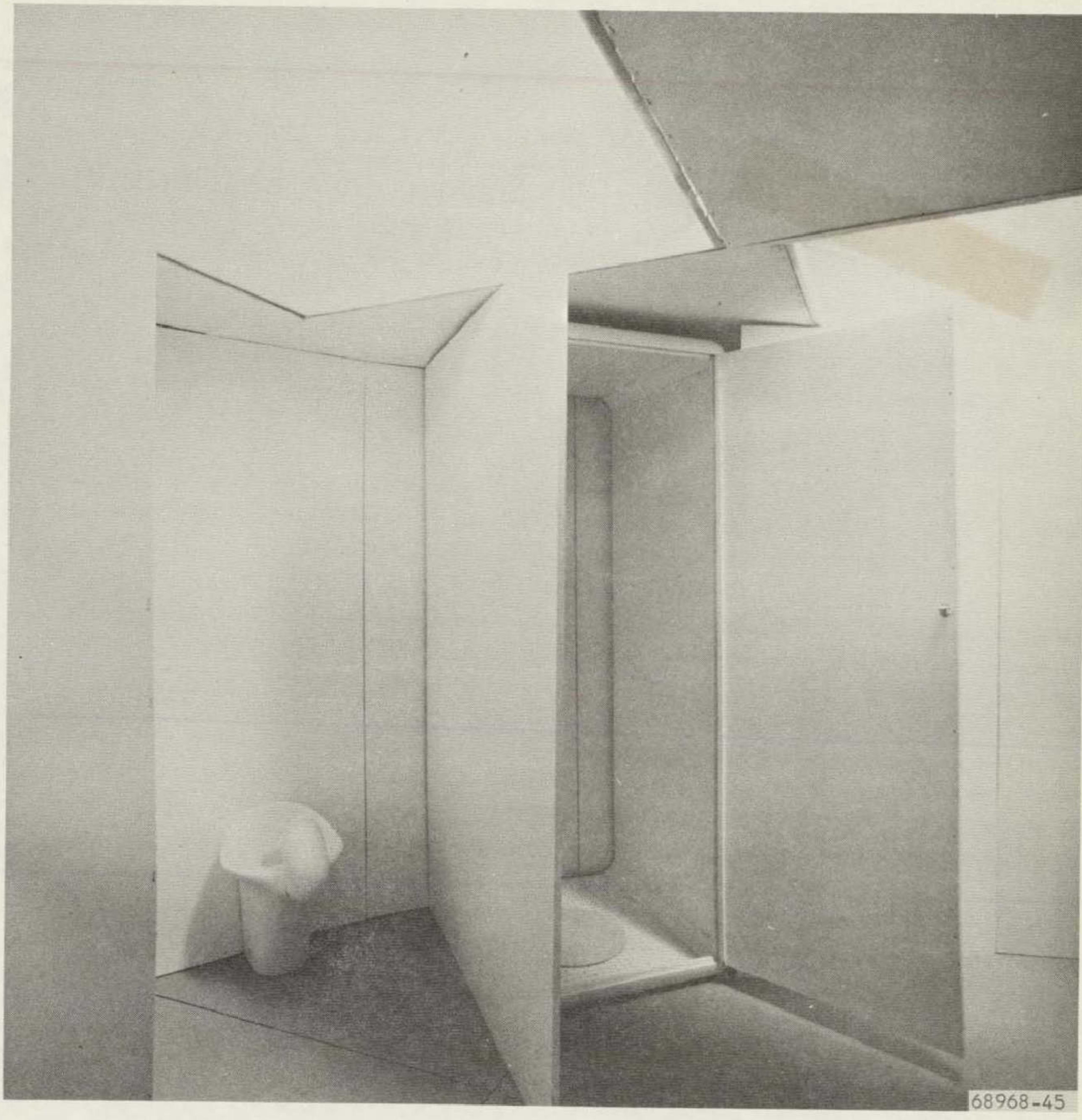


Figure 8-21. Zero-G Toilet and Shower

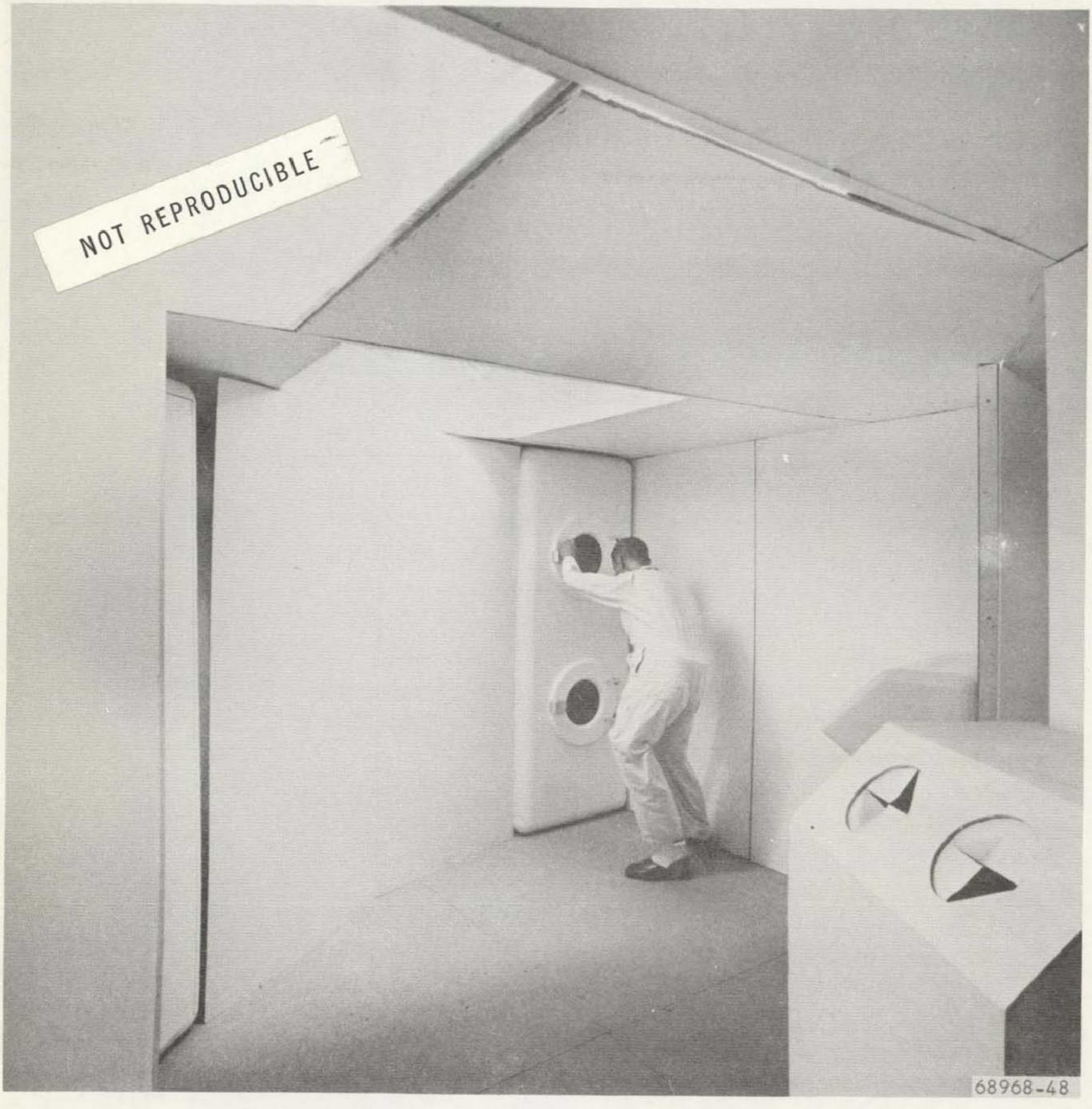


Figure 8-22. Subject Using Clothes Dryer

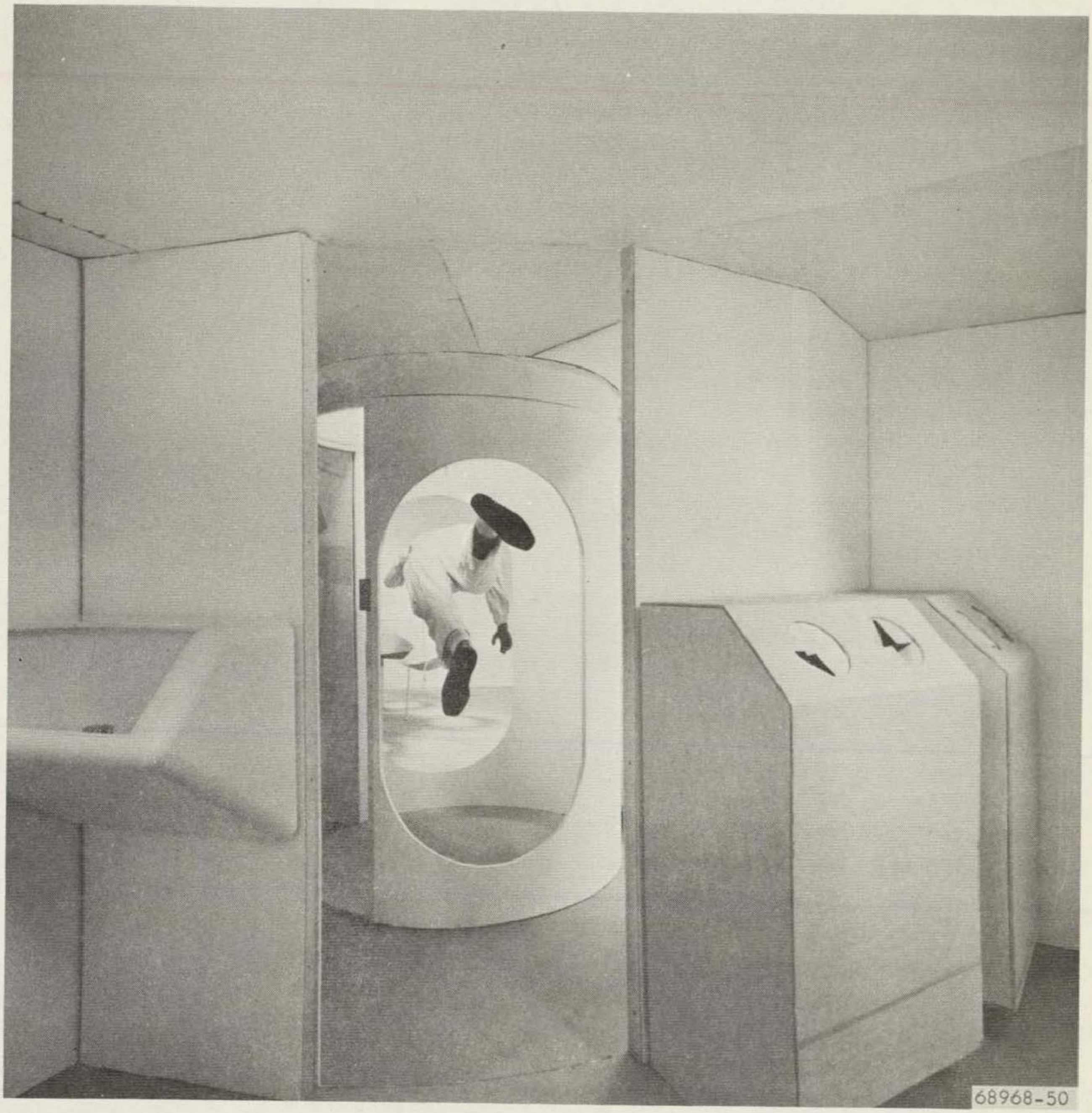


Figure 8-23. Subject Leaving Hygiene Area

CRITERIA AND STANDARDS

Criteria and standards for the hygiene area are listed below.

Criteria	Standards
1. Dispose of crew wastes.	1. Toilet, urinal, tissue, and trash receptacle.
2. Must be easily cleaned and disinfected.	2. Smooth surface with rounded corners. Color to show areas that need cleaning.
3. Provide a body cleansing area.	3. Showers, lavatories.
4. Provide a means for cleaning clothes.	4. Tumbler washer and dryer.
5. Must be easily accesible to other major areas.	5. Free access with planned traffic patterns for high-use periods such as after sleep periods.
6. Provide privacy.	6. Shower, toilet, and urinal enclosures.
7. Eliminate odors.	7. Air circulation through toilets, urinals, recirculated through charcoal filters.
8. Provide adequate local light for shaving (haircuts).	8. Light intensity equal to reading light requirements (60 to 100 ft-c)
9. Provide a spilled liquid retriever.	9. Portable suction device with a tank for collecting, storing, and transporting liquids to a receptacle.
10. Provide storage for cleaning materials.	10. Cleaning materials and disinfectants compatible with hardware and structure.
11. Control temperature for bathing.	11. 70° to $80^{\circ}F$.

Second-Level Functions (Hygiene Area)

The second-level functions providing for hygiene are (1) eliminate body wastes, (2) ensure body cleanliness, and (3) provide clean garments (fig. 8-24). These second-level functions can be subdivided further into the third-level functions that also are discussed herein. In the absence of a total mission analysis, these functions must be considered preliminary.

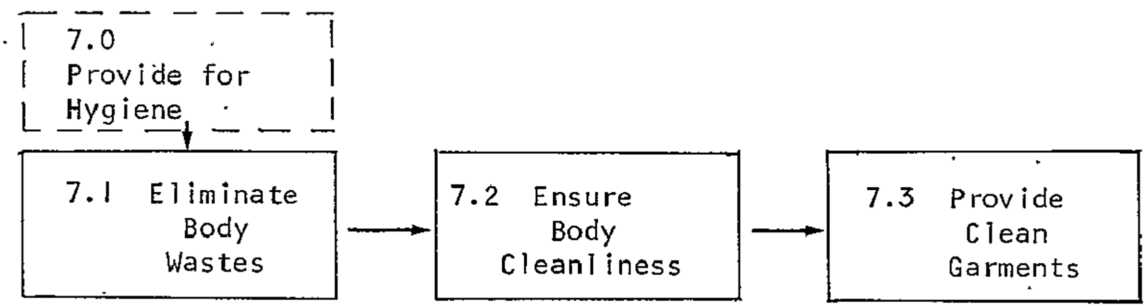


Figure 8-24. Second-Level Functions to Provide for Hygiene

Block 7.1--Eliminate Body Wastes

The elimination of body wastes is a function that must be accomplished if crew members are to survive in long-duration space flight. Waste material not passed from the body can cause distension of internal organs and decreased organ efficiency with increased toxicity. If some toxins are not expelled, eventual death will occur. Not only must body waste elimination be ensured; a method of containment and disposal of body wastes must be provided to preclude uncontrolled bacterial growth and contamination of crew members. The equipment that is used for this purpose should be designed such that crew members are encouraged to use the facility.

Block 7.2--Ensure Body Cleanliness

Provisions for cleaning the body during long-duration space flight must be made and scheduled cleansing periods must be established. Although there are individual preferences in frequency and extent of bathing, long periods without body cleansing should not be allowed. In addition to the obnoxious odors that result from metabolic wastes exuded through pores onto the skin, these wastes can cause increased skin sensitivity to particular environments, which causes chafing and sores that might become infected. Scheduled cleansing periods would reduce the probability of such skin problems occurring as well as minimize obnoxious odors that might affect the morale of other crew members.

• Block 7.3--Provide Clean Garments

Clean garments should be provided for the same reasons that the body should be kept clean. Skin chafing, sores, and infection can occur from metabolic waste products exuded through the skin pores and absorbed by the garments. Also, repugnant odors will occur that can increase crew tensions. Clean garments also supplement individual feelings of well being.

Third-Level Functions (Hygiene Area)

Eliminate Body Wastes

The eliminate body wastes function can be subdivided into the third-level functions shown in fig. 8-25. These are remove urine, dispose of feces, and remove vomitus. Further division of these functions results in the tasks described in the task analysis forms in this section.

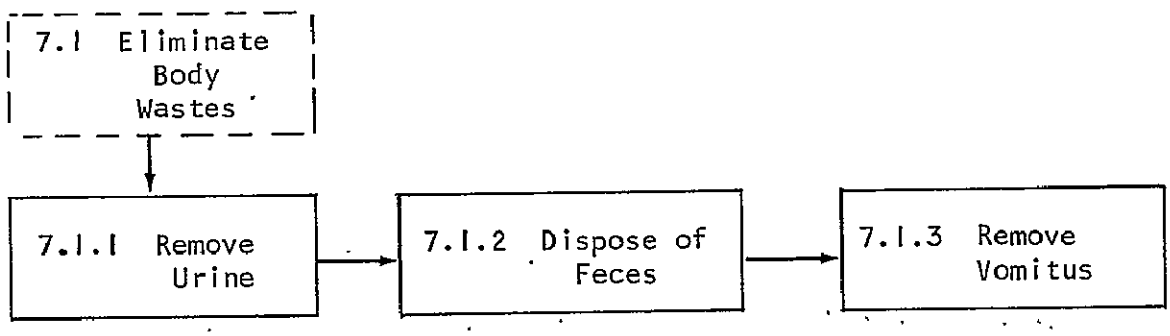


Figure 8-25. Third-Level Functions to Eliminate Body Wastes

Block 7.1.1--Remove Urine.- Urine must be removed from the bladder to prevent crew member death and subsequent mission failure. Urination in zero-g conditions is more difficult because the force of gravity normally is used to help drain the bladder and dispose of urine. Urination in zero-g therefore will be a more active, concentrated effort. Equipment must be designed to aid this process and to prevent the urine and urine odors from escaping into the spacecraft atmosphere. Since the medical aspects of long-duration zero-g space flight are not fully understood, urination ability and abnormal bladder distension that might result from zero-g habitation for extended periods should be monitored so that abnormalcies can be detected early enough to be treated effectively.

Block 7.1.2--Dispose of Feces. - Unlike urination, in which the force of gravity is of importance, defecation is accomplished through the muscular actions of internal organs that act to force the feces from the body. The crew members should be positioned such that opening of the anal sphincter muscles is facilitated. Removal and entrapment of the feces and fecal odors should be accomplished with minimal cleansing requirements.

Block 7.1.3--Remove Vomitus.- Vomitus resulting from motion sickness, disagreeable food, illness, or other causes should be removed before other crew members are exposed to it. Removal methods should be developed for both the condition in which the crew member has time to reach a specific facility before vomiting and the condition in which the crewmember vomits into the spacecraft atmosphere.

Ensure Body Cleanliness

The third-level functions for ensuring body cleanliness are wash body, wash hands, wash face, remove whiskers, provide oral hygiene, cut hair, and trim nails. These are shown in the logic block diagram of fig. 8-26.

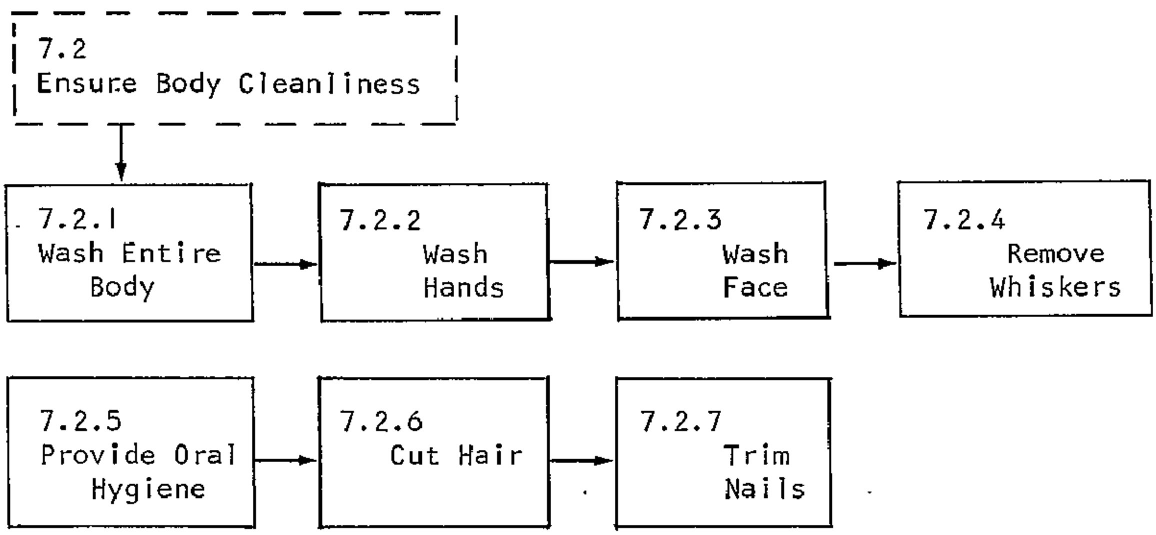


Figure 8-26. Third-Level Functions for Ensuring Body Cleanliness

Block 7.2.1--Wash Entire Body.- The entire body should be washed on a scheduled basis to minimize skin irritations and repugnant body odors. Provisions must be made for retaining both clean and dirty water droplets. Also, body washing should be accomplished without excessive difficulty or loss of time.

Block 7.2.2--Wash Hands.- A facility in which the crew members can wash their hands must be provided. Cleansing soiled hands is necessary when residues accumulated during the performance of one task might affect the astronaut's next task. For instance, a crew member working with poisonous chemicals should clean his hands before eating food. Cleansing the hands also is necessary when contaminants might be harmful to the skin. Provisions must be made for containment and disposal of the cleansing agents used for washing.

Block 7.2.3--Wash Face.- Perspiration, dirt, and grime must be removed from the face for both health and social reasons. Unsanitary facial oils can be transferred to bedding and provide a breeding ground for bacteria in the head region while sleeping. Perspiration must also be prevented from running into the eyes at an inopportune moment, especially during a hazardous task. In a social atmosphere, dirty, grimy faces are unacceptable for most occasions and can lead to crew feelings of discontent and lower morale.

Block 7.2.4--Remove Whiskers.- Long whiskers and beards should not be grown during long-duration space flights. Cleanliness and sanitation procedures are more difficult because of entrapment of food, mucous, saliva, vomit, and waste water. In addition, space suits are not designed for long facial hair growths. In cases of emergency or extravehicluar activities, long beards can (1) reduce the visual field, (2) increase growth of microorganisms within the suit, (3) reduce communication clarity, and (4) cause much discomfort from hair entanglement with helmet equipment and resultant pulling. Equipment for removing and containing whiskers should be provided.

Block 7.2.5--Provide Oral Hygiene.- Since dental equipment onboard the spacecraft will not be adequate for extensive dental care, a preventive tooth decay program in which the teeth and gums are brushed and cleaned daily is mandatory. Oral hygiene is also important for minimizing breath odor. Oral hygiene techniques that will preclude contamination of the spacecraft atmosphere include chewable dentifrice and conventional brushing. Brushing, however, must be performed only in a wet area to prevent liquid from escaping.

Block 7.2.6--Cut Hair.- As was the case for beards, long hair should not be grown during long-duration space flights because standards of cleanliness and sanitation become more difficult to maintain. In cases of emergency or during extravehicular activities, long hair can (1) reduce the visual field, (2) increase growth of microorganisms within the space suit, (3)reduce communication clarity, and (4) cause much discomfort from hair entanglement and pulling. Hair that floats into the eyes, nose, mouth, and ears can be very distracting and hazardous because the space-suited crew member can only maneuver his head within the helmet to try to eliminate the tension producing situation.

Block 7.2.7--Trim Nails.- Fingernails and toenails should be trimmed until they are even with the fleshy ends of fingers and toes, respectively. The nails should be cut straight to prevent ingrown or hangnail conditions from occurring. Nails should not be allowed to grow beyond the fleshy portion of the finger because dirt accumulation increases, tasks requiring finger dexterity may not be performed as well, and breaks and tears in the portions of the nail that are attached to the finger are more numerous. Also, the spacesuits are not designed for astronauts with long nails. Performing upper-torso tasks in the spacesuit would become extremely difficult with long fingernails because the glove would not fit properly. A fingernail that extended 1/2 inch beyond the end of the finger would result in the finger knuckles falling 1/2-in. below the suit glove knuckle positions. Bending the fingers of the pressurized glove would be much more difficult. Touch sensations would be reduced such that normal perceptual cues for controlling the muscles used to hold and grasp articles would be greatly distorted.

Provide Clean Garments

The third-level functions to provide clean garments are shown in fig. 8-27. These are (1) wash garments, (2) dry garments, and (3) maintain garments.

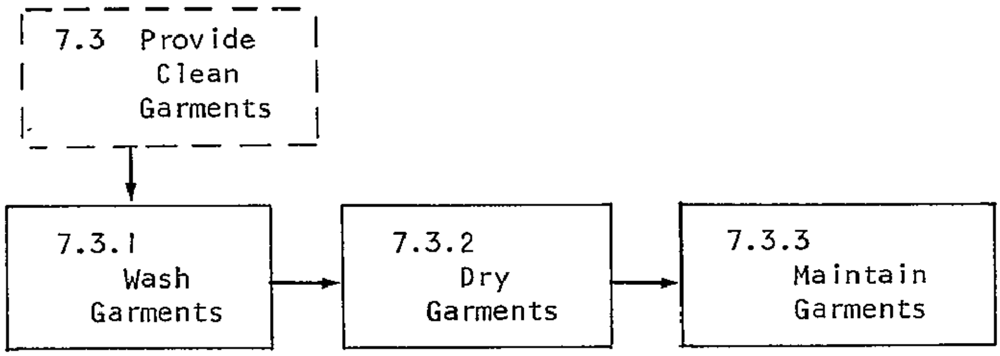


Figure 8-27. Third-Level Functions to Provide for Hygiene

Block 7.3.1--Work Garments.- Garments should be washed to remove sweat and other types of dirt. Soiled clothing that is not washed and worn can cause skin irritations and reduce crew member morale. Washing the garments also will minimize the noxious odors that can arise from soiled clothing. Provisions must be made for washing very bulky garments such as spacesuits and spacesuit helmets as well as the more conventional clothing.

Block 7.3.2--Dry Garments.- Garments are dried to prevent moisture from permeating the spacecraft and to provide for crew comfort. Wet clothing, if worn, causes chafing and other skin irritations. Wet clothes that are stored can mildew and decay much too rapidly. The kind of drying technique that should be employed is dependent upon the type of garment material. The space suits could be dried by simply hanging in the air because the material can easily withstand this process and moisture level is low. Warm air in a tumbler type drier will be adequate for other garments.

Block 7.3.3--Maintain Garments.- Garments should be maintained in a functional and neat condition. Maintenance activities can include sewing, stretching, ironing, storing, lubricating, and protecting. Maintenance of garments is important because of the resupply difficulty and cost. Weight also can be saved by maintaining garments instead of using throw-away type clothing.

TASK ANALYSIS

To further delineate hygiene area requirements for space station personnel, tasks to be performed by these personnel in the hygiene area are described in the following task analysis forms (fig. 8-27). As is the case for the functions analysis, these tasks are preliminary. When functions are reduced to the level

where the next step involves the manipulation of equipment, they become tasks (i.e., turn on water). Tasks and equipment can be finalized only after a total mission has been defined and studied. Task analysis forms have been completed for each hygiene function discussed in this section. The information loop is shown beginning with the task description information in, decision, and feedback. Performance deviations are the likely result of occurrences if the event does not proceed normally. Additional equipment includes those items such as hand tools that must be used to bring about the stated events. The location in the craft, frequency of occurrence, and elapsed time are all entered on this form. General items are carried in the remarks column along with an estimated volume of the hardware being considered.

TASK ANALYSIS OF: REMOVE URINE

THIRD-LEVEL FUNCTION NO: 7 1 1

7.0 PROVIDE FOR HYGIENE
7.1 PROVIDE FOR URINE ELIMINATION

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Prepare for urine elimination	Hygiene area	As required			Physiological urge	Position body, adjust equipment, and achieve interface	Visual, tactile	Improper interface	Liquid collector	Liquids must not be permitted to escape and float about the spacecraft interior. Use the liquid retainer to trap spurious liquids.
								Interface with urinal equipment achieved	Possible contamination of body and area if elimination is performed		
	Restrain body	Hygiene area				Body positioned	Grasp restraint unit and fasten	Visual, tactile	Restraint malfunction		
								Positive fastening design	Could cause contamination		
	Proceed with elimination	Hygiene area				Restraint fastened	Consummate the act of urination	Visual, tactile, audio, olfactory			
	Purge urinal system	Hygiene area				Elimination is complete	Activate purge system	Visual, tactile	Purge system malfunction		
								Light indicates purge operating, light indicates purge complete	Possible area contamination; repair necessary		

Figure 8-28. Task Analysis

TASK ANALYSIS OF: DISPOSE OF FECES

THIRD-LEVEL FUNCTION NO. 7.1.2

7.0 PROVIDE FOR HYGIENE
7.1 ELIMINATE BODY WASTES

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Prepare for fecal elimination	Hygiene area	As required			Psysiological urge	Position body to achieve interface with latrine	Visual, tactile	Improper position		
								Interface with latrine achieved	Could result in area and/or body contamination if elimination is performed		
	Restrain body	Hygiene area				Body positioned	Grasp restraint unit and fasten (hand, foot, or belt restraints are plausible)	Visual, tactile	Restraint malfunction		
								Positive fastening design	Could cause contamination		
	Proceed with elimination	Hygiene area				Restrained; fastened	Consummate act of defecation	Visual, tactile, audio, olfactory			
	Purge latrine system	Hygiene area				Elimination is complete	Activate purge system	Visual, tactile, olfactory	Purge system malfunction		Check cleanliness of toilet after each use
								Light indicates purge operating, light indicates purge complete	Possible area contamination, repair necessary		

Figure 8-28. (Continued)

TASK ANALYSIS OF. REMOVE VOMITUS

THIRD-LEVEL FUNCTION NO. 7.1 3

7.0 PROVIDE FOR HYGIENE
7.1 ELIMINATE BODY WASTES

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Prepare for oral elimination	Hygiene area	Random	1 to 3 min		Physiological upset or illness	Locate receptacle	Visual, tactile	Receptacle cannot be reached	Vomit bags	Spillage of liquids in areas other than the hygiene area can range from annoying to disrupting the mission if liquids penetrate certain equipment or instruments. This is the most likely cause of spillage in a dry area.
								Receptacle	Uncontrolled elimination inside spacecraft disrupts operation		
	Position body	Hygiene area or other	Random	3 sec		Receptacle located	Restrain body to interface with receptacle	Visual, tactile	Body cannot be positioned properly	Liquid retriever	
								Positive restraint	Spillage may result		
	Eliminate wastes orally	Hygiene area		1 to 5 min		Body properly interfaced with restraint and receptacle	Eliminate waste in receptacle	Visual, tactile olfactory, audio Wastes are deposited in receptacle	Wastes are not deposited in receptacle Spillage may result	Toilet	
	Purge waste disposal system	Hygiene area	Random	30 sec		Elimination is complete	Activate purge system	Visual, tactile, audio	System will not purge	Toilet opener	
								Purge system operating (light), purge complete (light)	Maintenance is required for normal system operation		

Figure 8-28. (Continued)

TASK ANALYSIS OF: WASH ENTIRE BODY

THIRD-LEVEL FUNCTION NO: 7.2.1

7.0 PROVIDE FOR HYGIENE
7.2 ENSURE BODY CLEANLINESS

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Prepare for bathing	Hygiene area	Once each 24 hr			Schedule or preference	Doff clothing and slippers	Visual, tactile			
	Open shower door	Hygiene area				Clothing removed	Grasp door lever and activate latch, swing door open; enter shower	Visual, tactile Positive operating latch door swings open	Latch malfunction		Shower system design must be such that no water droplets can escape. Vertical air flow inside shower will be required to insure water return to drain.
	Close shower door	Hygiene area				Inside shower	Grasp shower door lever and pull to closed position	Visual, tactile Automatic closing latch	Latch malfunction Delay of task		
	Start water flow	Hygiene area				Shower door closed	Activate water valves to on position	Visual, tactile Water on, adjust temperature by mixing	Water valve malfunction Possible hazard to mission; repair required		
	Complete shower	Hygiene area				Body clean	Activate water valves to off position	Visual, tactile Water off	Water valve malfunction Possible hazard to mission, repair required		
	Dry body	Hygiene area				Water off	Activate air dry system	Visual, tactile Dry air flows over body surface and over shower bulkhead surface	Air system malfunction Possible hazard to mission		

Figure 8-28. (Continued)

TASK ANALYSIS OF: WASH HANDS

THIRD-LEVEL FUNCTION NO: 7.2 2

7.0 PROVIDE FOR HYGIENE
7.2 ENSURE BODY CLEANLINESS

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Prepare for washing hands	Hygiene area	Random	1 to 2 min		Schedule or preference	Insert hands into unit	Visual, tactile Hands are in position		Wrist seal	
	Start water flow	Hygiene area				Hands inside unit	Activate water valves to open position	Visual, tactile Water flows. Temperature adjustment as required	Water valve malfunction Possible hazard to mission, repair required		Hand washing unit must be designed to prevent water droplets from escaping into spacecraft cabin.
	Complete washing of hands	Hygiene area				Hands are clean	Activate water valves to off position	Visual, tactile Water flow ceases	Water valve malfunction Possible hazard to mission; repair required		
	Dry hands	Hygiene area				Water off	Activate dry air system	Visual, tactile Dry air flows over hands	Air system malfunction Possible hazard to mission; repair required		

Figure 8-28. (Continued)

TASK ANALYSIS OF: WASH FACE

THIRD-LEVEL FUNCTION NO: 7.2.3

7.0 PROVIDE FOR HYGIENE
7.2 ENSURE BODY CLEANLINESS

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Obtain wash cloth	Hygiene area				Schedule or preference	Open storage compartment and select cloth	Visual, tactile	Wash cloths not available	Cloth or sponge	
								Wash cloths are available and removed	Possible delay of task		
	Prepare to wash face	Hygiene area				Cloth in hand	Insert hands and cloth into lavatory unit	Visual, tactile			
								Hands and cloth are in position			
	Start water flow	Hygiene area				Hands and cloth inside unit	Activate water valves to open position and wet cloth	Visual, tactile	Valve malfunction		
								Water flows wetting cloth	Possible hazard to mission, repair required		
	Prepare cloth for washing	Hygiene area				Cloth wet	Place water valves in off position then squeeze moisture from cloth	Visual, tactile	Cloth too wet		
								Cloth wet but not dripping	Excess water in cabin, possible hazard		
	Wash face	Hygiene area				Cloth ready; water off	Remove hands and cloth from lavatory; scrub face	Visual, tactile	Face not clean		
								Face is cleaned	Possible health hazard, may cause social problems		

Figure 8-28. (Continued)

TASK ANALYSIS OF. REMOVE WHISKERS ORAL HYGIENE CUTTING HAIR AND TRIMMING NAILS

THIRD-LEVEL FUNCTIONS NO 7.2.4. 7.2.5. 7.2.6 7.2.7

7.0 PROVIDE FOR HYGIENE
7.2 ENSURE BODY CLEANLINESS

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Remove whiskers	Hygiene area	As required for personal comfort			Personal needs	Utilize razor (electric or blade type)	Visual, tactile	Razor malfunction, lack of blades	Blades, cream	Electric razor must be designed to prevent whiskers from dispersing in cabin. Electric razor storage volume requirements = 36 cu in. blade razor, blades and cream volume requirements = 346 cu in.
	Oral hygiene	Hygiene area	Daily			Daily	Brush teeth	Visual, tactile Teeth are clean	Failure to perform task Possible dental problems; personal discomfort	Tooth brush dentifrice	Recommend digestible dentifrice, dental equipment storage requirements = 48 cu in.
	Cutting hair	Hygiene area	As required			Personal needs	Utilize hair clippers	Visual, tactile Hair trimmed to desired length	Clipper malfunction Personal discomfort, delay task	Hair clippers	Clipper design must be such as to prevent dispersal of cut hair (possible use of vacuum pickup on clippers)
	Trimming nails	Hygiene area	As required			Personal needs	Utilize nail clippers	Visual, tactile	Clipper malfunction	Nail clippers possible requirement for container	Nails must be confined as trimmed to prevent dispersal; volume = 1 cu in.

Figure 8-28. (Continued)

TASK ANALYSIS OF: WASH GARMENTS AND DRY GARMENTS

THIRD-LEVEL FUNCTION NO. 7.3.1 and 7.3.2

7.0 PROVIDE FOR HYGIENE
7.3 PROVIDE CLEAN GARMENTS

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Prepare for washing garments	Hygiene area				Schedule	Select garments to be cleaned	Visual, tactile	Failure to comply with schedule		
									May foster health and social problems		
	Open machine door	Hygiene area				Garments selected	Activate door latch and insert garment in machine	Visual, tactile	Door latch malfunction		Equipment design should be simple, i.e., single wash cycle and single dry cycle selection. These cycles could be preset to simplify circuit and gear design and establish load limits.
								Door swings open; positive opening latch	Will delay task; repair as necessary		
	Close machine door	Hygiene area				Garments in machine	Swing door to closed position	Visual, auditory	Door will not close		
								Door latches	Will delay task; repair as necessary		
	Activate machine	Hygiene area				Procedure	Activate switch to on position	Visual, tactile	Switch malfunction		
								Indicator light	Delay task; repair required		
	Wash garments	Hygiene area				Automatic	Automatic	Visual	Machine malfunction		
								Light or dial indicator	Delay task; repair required		
	Dry garments	Hygiene area				Automatic	Automatic	Visual	Machine malfunction		
	Remove garments	Hygiene area				Garments dry	Activate door latch and open; remove garments	Visual, tactile	Door latch malfunction		

Figure 8-28. (Continued)

TASK ANALYSIS OF MAINTAIN GARMENTS

THIRD-LEVEL FUNCTION NO 7 3 3

7.3 PROVIDE CLEAN GARMENTS

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Inspect for wear and damage	Hygiene area and sleep area	After each cleaning	5 min		Freshly laundered garment	Inspect for wear and tear	Visual, tactile Unusual wear indicated	Garment may be beyond repair	Maintenance kit	Preventative maintenance performed properly will greatly extend life of garments
	Repair	Sleep area	Random	5 to 20 min		Wear or damage located	Select material and tools to effect repair	Visual, tactile Repairs completed; suit functions normally	Unusually rapid wearout of garment		Detail repairs will depend upon selection of garment
	Stow for use	Sleep area	Random	2 min		Repairs to garment completed	Stow garment for future use	Visual, tactile Garment is stowed properly	Improper stowage may result in damage	Individual garment stowage device in sleep area	

Figure 8-28. (Continued)

SECTION 9

WARDROOM STUDY

9

WARDROOM STUDY

WARDROOM DESIGN RATIONALE

The wardroom is a multi-purpose community space where the entire crew can assemble at one time. Functions of this area show a time sharing between eating, recreation, exercise, and assembly. These multiple functions will require some moving of equipment or furniture between the end of one activity and the beginning of another. The design of wardroom equipment must allow for quick and easy change-over with a minimum of work and movement. For example, on the Tektite II project, the most common complaint was that events had to be stopped and the equipment stowed to make enough space for the next actitivy. If not carefully designed, multi-function spaces can create constant interruptions that become quite distracting, which results in inefficient work procedures.

Initially, medical tasks also were considered as a wardroom function due to their community nature. During the analysis, it became apparent that the wardroom would be in constant use and that treatment of medical problems in the wardroom would deny its use for other functions. The results of the medical study are included in this report. From brief investigation of other requirements peculiar to the operation of a medical facility (rest, quiet, etc.), it was concluded that medical problems should be resolved in a separate facility aboard the spacecraft. The medical area should be studied in detail for long-duration space missions, especially where there is an effect on spacecraft design. Items that require additional study and that should be included in future habitability analyses are:

(1) The amount of medical supplies required per man per mission

(2) Operating facilities

(3) Recovery room

(4) Disposition of corpses

The type of food selected is beyond the scope of this study; however, past data show that a storage volume of approximately 657 cu ft per 12 men per year is required. Because of this large volume and the uncertainty of the type of food that will be employed during long-duration flights, the wardroom volumes do not include the volume required for food storage; only the volumes required for preparaing, eating, and disposing the food are discussed herein.

Accumulation of refuse from food and beverage containers became a major problem aboard Tektite due to the lack of storage space. This information reinforces the design constraint to provide for refuse disposal and cleaning materials before problems arise that may cause a mission abort.

Round tables were compared with rectangular forms for conservation of volume when seating the same number of crewmen. Other geometric shapes with flat sides such as hexagons were considered, but were discarded because they have no advantage over round tables.

Design criteria must also consider wet and dry foodstuffs and beverages. Although beverages can be held captive by a liquid-gun dispenser, small amounts of liquid may inadvertently be dispensed. Ambient equipment must be designed to operate in the environment, and personnel must be trained to cope with small amounts of escaped liquids.

Group social interactions, both active and passive, are held in the large open volume of the wardroom. Active games are participated in by two men or small groups and require space for movement. Typical active games include darts, ball games, and other sporting activities. Passive activities include audiovisual, chess, card games (poker, bridge, etc.), and discussion sessions. Audiovisual recreation can range from movies to educational material where learning may be accomplished for the fun of it. Audio recreation will include musical and comedy tapes that can be listened to individually or by groups. Visual recreation such as reading, sketching, and writing generally is an individual activity that can be done in the wardroom or sleeping quarters. Visual recreation in the wardroom can include viewing slides and movies.

Exercise will play an important role in long-duration space flight. Its major function will be to offset the physiologic deconditioning that results in weightlessness. It will serve, however, to fill at least two other purposes related to the psychophysiologic well being of the crew members. Exercise has real value in terms of meeting an individual's need for self satisfaction through the maintenance of muscular development of his body as well as providing an outlet for venting excess energy and/or frustrations.

The space required for the medical facility, equipment, and supplies would fit in the wardroom volume, but the medical time in use prevents time sharing with other functions. A medical facility must be available around the clock for treatment, and in some cases illness will require full time use of the facility. Wardroom functions of eating, recreation, and exercise time share the volume on a rather close schedule, thus making this a community space. Putting a medical facility in the wardroom would disrupt the schedule for the other functions and create a breakdown of efficiency. Detailed analyses should be conducted of the volume required for medical air, location in the spacecraft and type and quantity of equipment and supplies.

Other uses of the wardroom are for crew assemblies. Assemblies may be for debriefing, entertainment, discussion of work results, crew assignments, or other forms of group information dissemination. Assembly is an important function because it allows information to be presented to the entire crew at the same time. This results in less confusion and more efficient use of time.

Information from the literature indicates that having the entire crew eat together is advantageous. Assembling the entire crew at one time instead of staggering the dining periods requires a larger volume wardroom. Link analyses

of eating were prepared for two major different types of activities: (1) having each man come to essentially a single food source, and (2) having multiple food sources.

For the first approach, crew members enter the wardroom, select their meal from storage displays, transport it to an oven or preparation device, and heat it, possibly through use of a hot-water injector or microwave oven. After the food is prepared, it is transported to a table for eating. After consumption, the debris is enclosed in the container, and the container is then transported to a refuse disposal or storage unit. During this dining period, much moving about is necessary for the entire crew, which requires additional volume for passing in the aisles. (See fig. 9-1.)

The second approach utilizes a food unit that stores, prepares, and retains both food and crew member. The crew members enter the wardroom and enter their designated restraints. Food is selected from the adjacent storage rack and placed in the oven located in the center of the unit. After the food is prepared, it is taken out of the oven and placed in the restraint for eating. Refuse is placed in the container and transported to the disposal site. (See fig. 9-2.) Since traffic is minimized by this arrangement, it is recommended as the volume saving approach. One characteristic of this type of food preparation unit is the lack of a flat table top. Although not required for dining, a table top may be useful for other functions such as games or writing.

Lack of variety was the most frequent complaint about food aboard Tektite in spite of a rather wide selection of available frozen meals. Some aquanauts particularly missed items such as salads and fresh fruit, which could not be included in the onboard food supply.

MEDICAL ASPECTS

The basic approach to ensuring the medical well-being and support of personnel during long-duration space flight is the avoidance of illness. Illnessess are best avoided, or decreased in incidence, by prevention through a vigorous program of astronaut selection. The selection process should be designed to identify any predisposition to functional or organic illness that could interfere with inflight performance. The Space Medicine Advisory Group (SPAMAG) has identified among these susceptibility to motion sickness, seizures, abnormal behavior, functional bowel disturbances, allergies, migraine, Meniere's disease, gall bladder colic, and kidney stones. An accurate medical history of each potential crew member, as well as clinical evaluations of his responses to various stressors such as increased gravity fields, high carbon dioxide, etc., will be of extreme importance.

Another aspect of illness prevention is preflight isolation of crew members to minimize the potential of cummunicative diseases. This technique is currently being used, but the quarantine criteria probably will need to be tightened for participating in longer missions.

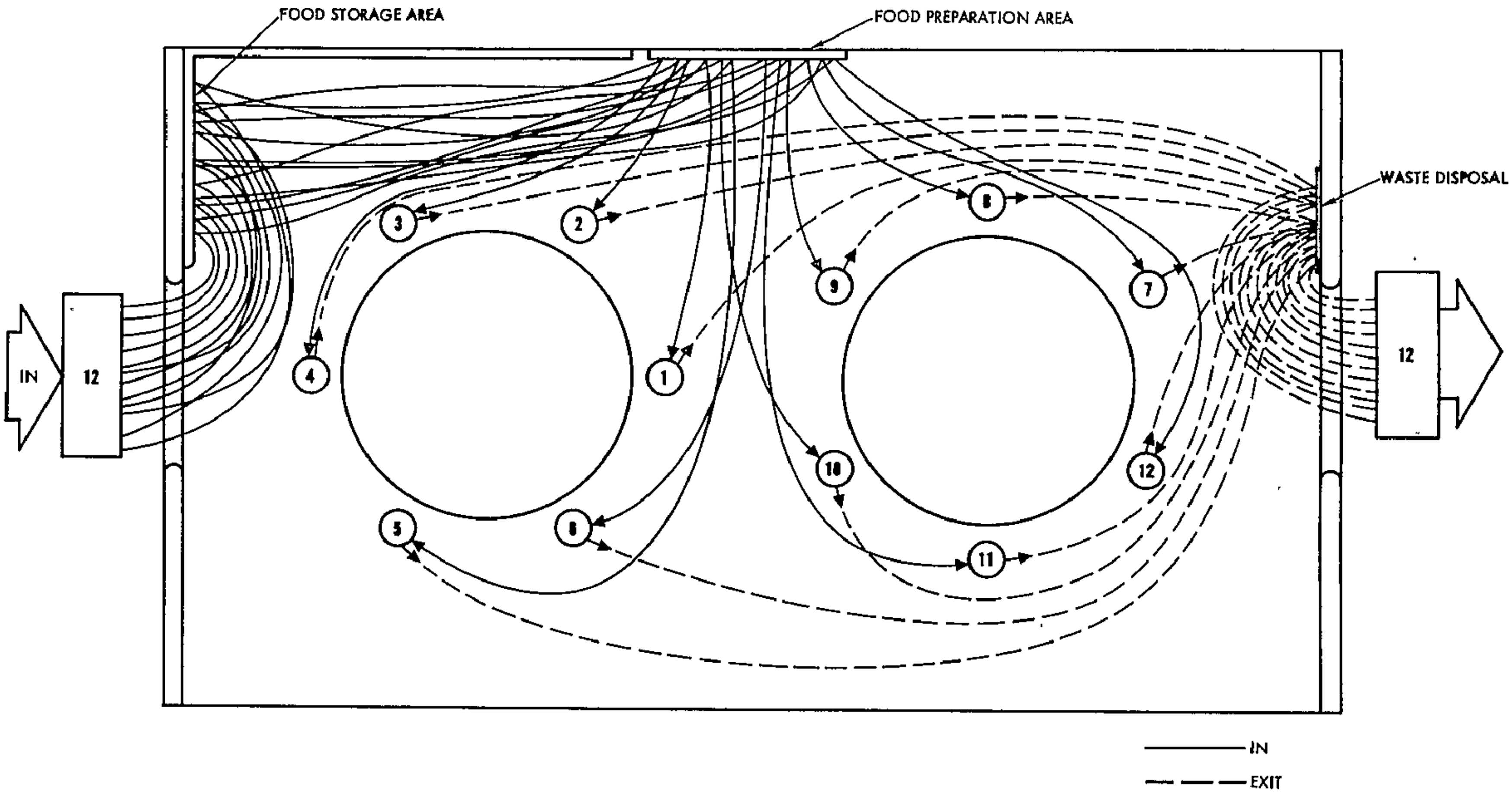


Figure 9-1. Typical Traffic Flow for One Meal with Individual Pick Up and Food Preparation

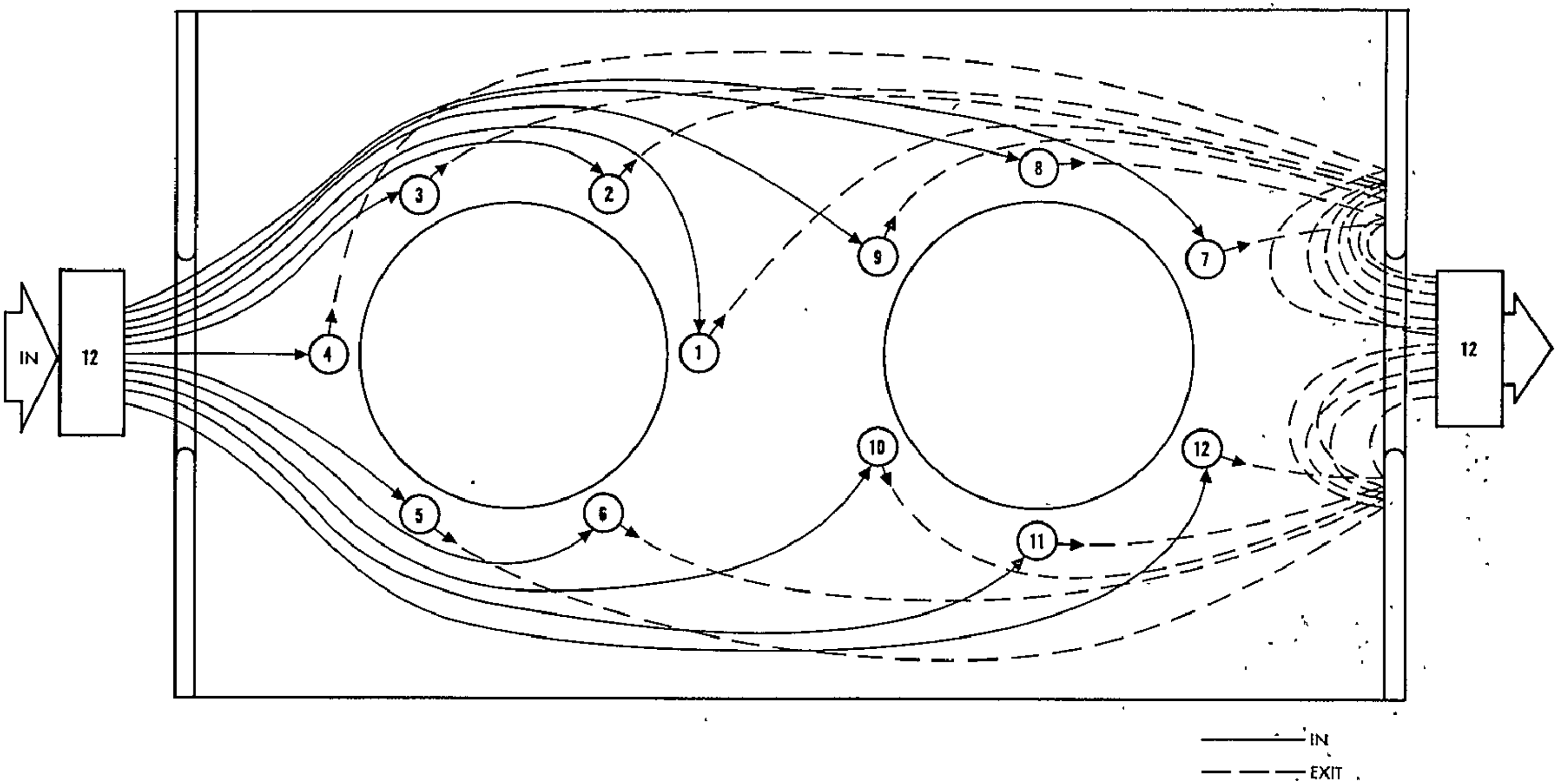


Figure 9-2 Typical Traffic Flow for One Meal
With Food Prepared/Placed at Table

Medical Personnel

A physician would be highly desirable as a crew member, both to provide medical surveillance and treatment and to perform physiologic and medical experiments. A foremost consideration is whether a medical doctor can be fully utilized as a crew member. The feasibility of having a medical doctor as a crew member is related to the division of skills of the entire crew in terms of the totality of tasks required. This consideration would certainly require that one member of a crew of twelve be responsible for more than strictly medical care.

A medical doctor who is expert in environmental physiology would be useful in operation and maintenance of life-support systems, and he could be trained in tasks related to laboratory missions. On the other hand, the diversity of other tasks required of the crew might dictate that crew members with other skills be preferred; in this case, one or more of them would be given adequate medical training and experience in handling emergencies. An individual with the equivalent of military corpsmen training could handle most situations easily. A backup man would be essential. All crew members should be thoroughly indoctrinated in first aid procedures. Since communications will be available almost continuously for obtaining medical advice, this approach is feasible.

Medical Equipment and Supplies

A medical chest with drugs and supplies must be available for symptomatic treatment or for treatment of specific diseases that might occur. Such diseases have been identified by SPAMAG as:

(1) Respiratory illness

(2) Urinary infections and stones

(3) Gastrointestinal disturbances such as mucous colitis, gastritis, peptic ulcer, or diarrhea of infectious or other origin

(4) Cardiac arrhythmia

(5) Disturbed emotional state

(6) Aspiration of foreign body

(7) Minor trauma

(8) Burns

(9) Foreign body in the eye

The nature of the supplies and equipment will be determined in part by the medical personnel providing treatment. If a physician is a crew member, he must, as a minimum, be able to perform the services and procedures routinely carried out in the emergency room of any busy metropolitan hospital.

Since the volume and number of these services will be drastically different on a space mission, however, the equipment need not be as elaborate, but it must be more flexible and adaptable to multipurpose use. Both medical and surgical problems should be anticipated. Typical equipment and medicines required for the former are listed below:

(1) Stethoscope

(2) Combination otoscope-ophthalmoscope

(3) Sphygmomanometer

(4) Thermometer

(5) Reflex hammer

(6) Small sharp objects (pins), 2 or 3

(7) Flashlight

(8) Tongue depressor

(9) Cotton tipped swabs, several gross

(10) Microscope

(11) Hemoglobinometer

(12) Aspirin tablets, 1000 (5 gross)

(13) Antibiotics, associated tablets as available (e.g., penicillin, 200; tetracyclines, 200; sulfas), and also in the injectable, reconstitutable form

(14) Analgesics/narcotics, meperidine, 20 50-mg ampules; morphine sulphate, five 1/4-gr ampules

(15) Hypnotics, secobarbital, 250 100-mg capsules

(16) Local anesthetics, procaine HCl, 100 10-cc ampules

(17) Antispasmodics, belladonna alkaloid or as available

(18) Antacids, magnesium sulphate

(19) Antihistamines, triplenamine sulphate

(20) Epinephrine, as stimulant and decongestant in suitable forms

(21) Meprobamate and/or phenothiazides

(22) Mild laxative

(23) Kaopectate

(24) Steroids, assorted

(25) Small sealed containers, specimen bottles, miscellaneous

(26) Small slides, staining materials

(27) Counting chamber, red and white cell pipettes, four each

(28) Small clinical centrifuge

(29) Miscellaneous topical ointments and solutions

The equipment listed above should enable the physician to handle most medical problems with which he might be confronted. It would be uneconomical from a weight and payload standpoint, however, to use ordinary clinical equipment like that used by most doctors. For example, an ordinary otoscope, which uses battery power, could be replaced by a unit designed to operate directly from the spacecraft power supply. Since a good deal of physiological research will doubtless be planned as part of the mission objectives, much of the required medical equipment will be provided in the spacecraft for scientific purposes. Depending upon the equipment planned for other purposes, therefore, some items from the above list could be eliminated. It is highly probable, for example, that the sphygmomanometer can be eliminated from the list; since blood pressure measurements will doubtlessly be part of the scientific study, one will be included in the vehicle equipment list. It is likely that a newer technique than the conventional aneroid bulb will be used. It is also likely that a microscope and a thermistor thermometer will be included in the list of scientific equipment. The reflex hammer also could be eliminated; the physician could improvise and use the side of his hand or the edge of his stethoscope. The flashlight can be replaced by a small portable trouble light, which also will probably be a part of the vehicle equipment.

The handling of surgical problems will require equipment and materials dissimilar to those used for any other purpose in the space vehicle. Fortunately, most of this equipment is lightweight, requires relatively small volume, and is currently available on the commercial market. Many of the expendable materials such as scalpel blades, sutures, and surgical needles may be obtained in sealed prepackaged containers or packets which require very little space for storage.

The surgical equipment should be packaged into a small neat set which will require less space than a military footlocker (approximately 12 by 24 by 36 in.). The amounts of materials carried must be calculated in light of various forms of medicines and equipment available or developable during the time frame for which flight is programmed. The medical officer who is to use the equipment must have the prerogative of making certain additions or deletions. His familiarity with a particular technique or instrument will be the final factor that determines whether the material is to be on board.

All of this equipment should weigh approximately 200 lb. Heavy items of equipment such as the microscope, which are also necessary for scientific uses, can be shared for medical purposes. Dual-purpose equipment and the sharing of identical items will greatly reduce the weight of the medical equipment.

Special care must be taken to ensure that accidental exposure to medicines or materials does not present a toxiferous hazard to the crew. Furthermore, all containers must be sealed tightly and adequately when the material is not in use. For example, a common clinical mercury thermometer represents a potential hazard to all occupants if it should be broken. Therefore, either a thermistor or bolometer should be used in its place. The necessity for carrying plaster of paris for splints should be eliminated because of both the water requirement and the necessary weight involved. Air-inflatable splints would be more convenient; in fact, if portions of the space suits can be detached, it may be feasible to use only a space suit arm or leg with an appropriate seal as an air-inflatable splint. Typical items of surgical equipment that should be stored on board are as follows:

(1) Hemostats, 10

(2) Scissors, assorted, 5 pair

(3) Clamps, assorted

(4) Scalpels, 5

(5) Assorted scalpel blades, 50

(6) Thumb forceps, 5

(7) Tweezers, 2

(8) Probes, 2

(9) Syringe cases, 5

(10) Phisohex or other suitable skin sterilizer

(11) Needle holders, 5

(12) Muscle spreaders, 2

(13) Gauze dressings, assorted

(14) Elastic bandage

(15) Nonstick (Telfa) dressing

(16) Suture material, silk, monofilament nylon, etc.

(17) Plasma, 5 units

(18) Burn ointment, 5 tubes

(19) Assorted air-inflatable splints, 5

(20) Catheters, 3

(21) Drains, assorted rubber/plastic

(22) Cling dressing

(23) Instrument sterilizing solution

(24) Surgical drapes, 4

(25) Needles, assorted

The equipment listed should enable the medical officer to cope with most foreseeable problems. Ingenuity as well as foresight will be essential. It may be advantageous to type and cross-match blood samples for the various crew members so that direct transfusions could be made between compatible individuals if the need arose. A primary study directed at the medical requirement would appear to be indicated and well worthwhile.

If a physician is not a member of the crew and medical services are provided by a crew member with limited medical training, the nature of the medical equipment and supplies will be quite different. A partial list of items that might be included is given below.

(1) Stethoscope

(2) Combination otoscope/ophthalmoscope

(3) Sphygnomanometer

(4) Thermometer

(5) Pins

(6) Tongue depressor

(7) Flashlight

(8) Cotton-tipped swabs

(9) Motion sickness injectors

(10) Pain supressor injectors

(11) First aid ointment

(12) Eye drops

(13) Nasal spray

(14) Compress bandages

(15) Adhesive bandages

(16) Ophthalmic ointment, antibiotic

(17) Antibiotics

(18) Nausea medicine

(19) A stimulant

(20) Pain killer

(21) Decongestant

(22) Diarrhea medicine

(23) Aspirin

(24) Sleeping pills

(25) Burn ointment

(26) Hemostats

(27) Forceps

(28) Needle holder

(29) Needles

(30) Suture material

(31) Scissors

The use of these supplies would occur only with concurrence and medical advice from ground control. However, since communication loss is a possibility, a microfilm reader and/or audiovisual display with required reference material would be essential for treatment. This would also be important in compiling data for transmission to a medical monitor on the ground for diagnostic purposes.

Impact of Long-Duration Missions

The medical implications of long-duration exposure in the unusual gaseous environments of spacecraft coupled with weightlessness are not completely understood. Many potential effects can be evaluated only in the spacecraft environment, and therefore contingency planning must be undertaken. It is beyond the scope of this work to evaluate all aspects of potential medical problems, and only those which impact on habitability design will be considered here.

Long-duration flight will require physiologic monitoring of the crew members for (1) the detection of subtle physiopathological effects and (2) evaluation of fitness. Fitness evaluation would include determination of acute illness and of physiologic deconditioning in response to weightlessness.

A privacy area must be set aside in the habitat design for the performance of medical evaluations. This area could be provided in the wardroom through use of a privacy screen. It would seem more acceptable, however, to provide the medical crew member with a slightly larger sleeping area and to include the examination area there. This would allow greater privacy, better access to medical supplies that would be stored in the same area, and a better environment for the medic-to-patient relationship. This dispensary area should probably include a surface with straps that could be used as an examining table..

Special filters, etc., should be provided in the environmental control system so that the dispensary space could be used as an isolation room. One of the unknown aspects of long-duration space flight is the effect of abnormal atmospheres on the normal bacterial flora of man. Man normally carries pathogenic types of bacteria, e.g. staphylococcus aureus, streptococcus sp., etc., in a nonvirulent form. Exposure to abnormal atmospheres may cause bacterial mutations to virulent forms and/or reduce the physiologic resistance of the crew members to their normal flora so that pathological conditions could occur. Under these conditions, complete isolation of an infected crew member might be essential.

The requirement to prevent physiologic deconditioning of the crewmen imposes the need to:

(1) Maintain neuromuscular tone

(2) Maintain cardiovascular tone

(3) Minimize calcium mobilization from the skeletal system

Two techniques must be used to prevent physiologic deconditioning. Exposure to lower body negative pressure (LBNP) to increase the work of the cardiovascular system by forcing the system to pump against an increased hydrostatic pressure head is essential to minimize cardiovascular deconditioning. This will require the presence of one or two LBNP units, which might be positioned in the dispensary, wardroom, or in a scientific experiment area. The use of LBNP should be coupled with an exercise regime that would force work loads incurring heart rates of approximately 140 to 160 beats/min for 10 min. Bicycle ergometers or the Air Force total body exerciser developed for the Manned Orbiting Laboratory could serve this purpose. Two units of either type should be located in the wardroom.

Fitness is particularly essential for reentry, and the crew members must be able to withstand the imposed environmental stresses and perform the work incidental to survival after impact. They must also be able to do the professional tasks while undergoing these stresses. The following forms (figs. 9-3 and 9-4) were developed by SPAMAG as guidelines for developing onboard physical evaluation techniques.

FOOD AND WATER

It is often stated that for space missions of less than 30 days, the dietary needs of man are essentially the same as those of men of similar physical stature on earth. Extension of this approach to longer missions cannot be made with assurance. The long duration effects of hypodynamic environments are poorly understood. However, man's dietary needs should be estimated to exceed man's minimal maintenance requirements.

In addition to dietary maintenance, psychological responses to food form, taste, texture, etc. will be a major aspect of feeding during extended-duration space flight. To be satisfying, food must be acceptable, and this has little relation to the nutritional composition and values of the food. Any diet should be tailored to provide a variety of familiar foods that allow for individual hunger and satiety patterns. The nearer the diet comes to being like home-cooked meals, the more acceptable the food will be to the crew.

In determining a dietary regime, the behavior aspects of food, food preparation, and eating must be considered. The number and size of meals must allow for programming of eating with task performance, and provide small enough portions to prevent a large bolus of food in the stomach. Three meals should be available for eating at 4- to 5-hr intervals. In addition, a snack should be available during leisure time. A nibbling pattern is frequently encountered among humans in chronic anxiety producing situations; this should be satisfied. Monotony should be avoided under all circumstances.

Basic Nutritional Requirements

The data of table 9-1 represent the allowances for normal maintenance and performance as well as prevention of disease which the Food and Nutrition Board of the National Academy of Science-National Research Council has recommended. These allowances, which are at present under review by the NAS-NRC, all exceed the minimal maintenance requirement with the possible exception of energy.

In addition to these allowances, it has been suggested that the energy requirements of the anticipated stresses of space flight can be met with the following alterations to the NAS-NRC recommendations.

Energy: 2800 kcal/man/day.

Protein: NAS-NRC has recommended allowance of 1 gm/kg of body weight/day.

PHASE I: LIFE SUPPORT RECOMMENDATIONS

DAYS 7 AND 21 OF EACH MONTH

Body weight centrifugal or best substitutes ______________________

Times V. C. ______________________

Flack ______________________

Submaximal exercise with chest lead V_4 ______________________

ECG alterations ______________________

Max. heart rate ______________________

Recovery time (min) heart rate ______________________

Symptoms: Pain ______________; Palpitation ______________;

Dyspnea ______________; Fatigue ______________

DAYS 14 AND 28 OF EACH MONTH

Medical Examination:

Laboratory

Blood: Morph. ______________ Eosinophile Ct. ______________

Hematocrit: ______________ Bl. vol. or best substitute ______________

Urine: Glucose ______________ Proteins ______________

Bilirubin ______________ Ketones ______________

Stool: Gross abn. ______________ Occult. bl. ______________

Estimation of Fitness for Reentry:

Prof. qualif.: simulation test.

Hard work: substitute capacity test for submaximal exercise test.

High-G load: simulation or best substitutes.

1-G Load: simulation or best substitutes.

Figure 9-3. Bimonthly Evaluation Sheet

Item	Tolerance limits**	Experiment required: Ground-based exper.	Experiment required: Space flight exper.	Recommendations or comments*
General physical medical evaluation				
Laboratory				
Blood				
Morph.				
Eosinophile count				
Hematocrit	Δ10%			OBAI
Blood vol. or best substitutes		Yes	Yes	
Urine				
Glucose	Presence			OBAI
Proteins	Presence			OBAI
Bilirubin	Presence			
Ketones	Presence			OBAI
Stool				
Gross abn.				?OBAI
Occult bl.				OBAI
Est. of fitness for reentry				
Prof. qual		Yes	Yes	Simulation test
Hard work		Yes	Yes	Substitute capacity test for sub-max. exercise test
High-g load		Yes	Yes	Simulation or best substitutes
One-g load		Yes	Yes	Simulation or best substitutes

Figure 9-3 (Continued)

Item*	Tolerance limits**	Experiments required		Recommendations or comments*
		Ground-based exper.	Space-flight exper.	
Body wt (centrifugal or best substitute)	A ±15%	Yes	Yes	OBAI
Respiratory				
Timed vital capacity			Yes	
Status of volume velocity loop				
Calibrated		Yes	Yes	
Valsalva maneuver (Flack test)				
Heart				
Submaximal exercise with chest lead V_4 until heart rate stabilizes		Yes	Yes	Equivalent to 3-man modified Harvard Step test
ECG alterations	Coronary disturbance evidence of coronary heart disease, bundle branch block	Yes	Yes	OBAI
Max. heart rate	Inc 10 - 15%		Yes	OBAI
Recovery time (min) heart rate		Yes	Yes	
Symptoms				
Pain				OBAI
Undue dyspnea				OBAI
Undue palpitation				?OBAI
Undue fatigue				?OBAI

Figure 9-3 (Continued)

ASTRONAUT BIOMEDICAL CARE DAILY EVALUATION OR FLIGHT RATING

Name or initials__________ Date______ Hour______

Estimate* of fitness, mental__________ physical__________

Estimate# of performance in professional tasks__________

Any drugs other than vitamins__________

Any indication of illness______ disorder______ injury______ infection______

Sleep: 24 hr total____, No. periods____, Sufficient______;Insufficient______

Mental attitude: Usual____, Bored____, Irritable____, Anxious____; Phys restlessness____

Headache______. Ocular disturbance______. Visual disturbance______.

Abnormal odor______. Abnormal taste______. Tinnitus______. Vertigo______.

GI Food: ate all____ or ____% of ration. Appetite: Good______ Fair______ Poor______

Indigestion__________. Nausea__________.

B. M , No. __________ Char.__________.

HOH: Drank all__________% __________ ration.

Resp Pain______, cough______, sputum______; aspirate foreign material______.

C-V: Unusual dysp______, unusual palpitation______; substernal pain______.

G-U Urin No. x 24 hr______; pain______, burning______; urgency______

Neuromuscular Pain______. Weakness______ Tremor______. Coord______.

Skin normal______, Sweat normal______; Fatigue*______.

Other comments:__________

TO BE FILLED IN BY BIOMEDICAL REVIEWER

Oral temp.______ BP______ PR______ RR______.

General appearance__________ Color__________.

Performance scores, Prof Tasks__________? Exercise__________.

Concordance of subjective and objective evaluations: Good______ Fair______ Poor______.

Estimated fitness for reentry** Prof.__________ Work__________.

Action items

Onboard__________

Consult ground-based observer__________

Action taken__________

* Based on 10-point score. 5 = usual; 10 = best score.

** 10 = very fit, 1 = unfit.

\# Based on load/time/accuracy: 10 = best, 5 = usual; 1 = worst.

Same for all days except every 7th and 28th.

Figure 9-4. Daily Evaluation Sheet

TABLE 9-1

RECOMMENDED DAILY DIETARY ALLOWANCE FOR AVERAGE U.S. MALE PERFORMING MODERATE PHYSICAL ACTIVITIES IN A TEMPERATE ENVIRONMENT

Age, years	Weight, kg	Height, cm	Calories, kcal	Water	Protein, gm	Fat, gm	Carb, gm	Calcium, gm	Iron, mg	Vit A, I.U.	Thiam, mg	Ribo, mg	Niacin, mg equiv	Ascorbic Acid, mg
25	70	175	2900	1 ml/ kcal expen- ded	70	97	437	0.8	10	5000	1.2	1.7	19	70
35-55	70	175	2600	1 ml/ kcal expen- ded	70	85	389	0.8	10	5000	1.0	1.6	17	70

Fat: Conserve weights and space but must be limited to 158 gm/man/day and 50 percent of total calories to avoid physiological consequences such as ketosis and nausea.

Carbohydrates: Content of poorly digested carbohydrates minimized to decrease intestinal fermentation and fecal residues; crude fiber content limited to 1 percent of total dry solids.

Water: The water requirements for space operations exceed in many situations the 1 mg/kcal recommended as a standard allowance for temperature climates.

Minerals: The NAS-NRC has recommended allowance of (in gm/man/day) calcium, 0.8; phosphorus, 1.2; magnesium, 0.35; sodium, 4.0; potassium, 3.0; iron, 0.10. It has been recommended that water consumption of > 4 liters/day would require 1 gm additional NaCl for each liter of water. Potassium should be limited to about 1 gm/1000 cal/day.

Vitamins: To be given as a separate tablet or capsule. The following supplement, per man per day: thiamine, 2 mg; riboflavin, 3 mg; niacin, 20 mg; pyridoxine, 5 mg; pantothenic acid, 10 mg; folic acid, 0.5 mg; vitamin B_{12}, 2 mg; biotin, 0.5 mg; choline, 1 gm; vitamin A, 4000 USP units; vitamin D_2, 400 USP units; vitamin K_1, 1 mg; ascorbic acid, 70 mg.

Trace minerals: The use of a variety of foods in the diet will assure the presence of at least some trace minerals. It is unlikely that an influence of marginal supply of these would be manifest in several weeks, but it would be desirable to ascertain mineral and water content so that intake level may be known for future reference.

Food and Feeding Considerations

A precise specification of the contents of a meal, its packaging, and method of dispensation cannot be given at this time. From a review of the literature (refs. 79, 80, and 81), fixed limits and probable values of weight and volume can be calculated. A consideration of the energy and density values for carbohydrate, fat, and protein leads to the conclusion that fat is the most energy dense foodstuff. An approximate value for the energy density of fat (9 kcal/gm and 0.96 gm/cc) is 8.64 kcal/cc. The comparative and again approximate value for carbohydrate (4 kcal/gm and 1.4 gm/cc) and protein (4 kcal/gm and 1.4 gm/cc) is 5.60 kcal/cc. Thus, to provide a daily caloric value of 2800 kcal/man, 325 gm of fat are required (this figure includes a 13.3 gm/man-day allotment of essential minerals as specified in ref. 79. For a 12-man-year mission, the absolute minimum food weight (2800 kcal/man-day) equals 1,420 kg (or 2,920 lb), and the corresponding volume equals 1,480 liters (or 51.9 cu ft.). A similar consideration of carbohydrate or protein (both have the same energy density value) yields values of 3060 kg (or 6750 lb) and 2.190 liters (or 77.4 cu ft.).

The values of food weight and volume just presented establish the minimum limits if just the caloric requirements are considered. A more realistic appraisal can be reached by considering acceptable mixes of carbohydrates, fats, and proteins. Table 9-2 was compiled from fig. 14-6 of ref. 79.

TABLE 9-2

12-MAN-YEAR FOOD REQUIREMENT (2800 KCAL/MAN-DAY)

Diet composition (gm/man-day)			Volume		Weight		Density	
Carbohydrate	Fat	Protein	l	cu ft	kg	lb	gm/cc	lb/cu-ft
530	44.5	70	2,190	77.5	3,290	7,250	1.50	93.5
275	158.	70	2,050	72.3	2,800	6,180	1.37	85.6

*Diet includes 90.5 gm (0.20 lb) of ingestible bulk plus 13.3 gm (0.029 lb) of essential minerals.

Note particularly that these figures do not include packaging or water for reconstitution. Vanderveen (ref. 80) notes that for the Gemini spaceflight the packaging weight equaled 40 percent of the total weight of a meal. What the meal density will be when the 12 men who are the subject of this study step into their spaceship cannot be stated. If present technology is to dictate more realistic values of meal density, then fig. 14-8 of ref. 79 indicates that for moderate acceptability,3000 kg (6,500 lb) of food will occupy a volume of 15,200 liters (535 cu ft) instead of 2,120 liters (75 cu ft). Stated another way, the more like home cooking the meal is, the lower will be its energy density.

It has been suggested that the space behind the wardroom will be used to store food. The total volume of this space is approximately 5,010 liters (177 cu ft). Thus the wardroom can store approximately one-third of the years supply of food. Considerably more research will be necessary before food choices and method of preparation and packaging can be more realistically ascertained.

Potable Water

Based on the actual fluid requirements during spaceflight, the Space Medicine Advisory Group has recommended that the amount of ingestible water per man should be 2.5 liters per day (1 cc per calorie of food). During normal operations, water intake should be sufficient to maintain the urine at a specific gravity of 1.015 or less at a volume of at least 1 to 1.5 liters per day. This is necessary to avoid the production of urinary gravel and should be consumed in fixed quantities on a programmed schedule. This recommendation was made for

sedentary astronauts in an orbiting vehicle in a cabin functioning at a nominal comfort mode. During periods of increased activity, the criterion of 1 cc of water per calorie of food can be used to adjust to the appropriate activity load.

Under emergency conditions that may limit the availability of water, the minimal basal requirements for water become significant and may be the controlling factor limiting life. The absolute minimum obligatory output of urine has been found to be 280 to 300 ml/day. Assuming a minimal insensible water loss of 500 ml/day and zero fecal loss, the total water input must equal 800 ml; this is in close agreement with the empirically derived value of 1 liter/day. This absolute minimum is still hazardous because the environment is assumed to be so controlled and stress-free that insensible loss is kept to its lowest level; also, extra losses through sweating during excess activity, obligatory diuresis, and other pathways are not considered.

Based upon the value of 2.5 liters per man per day, the drinking water storage volume requirement for 12 men during a 365-day mission would be approximately 390 cu ft.

Wash and Waste Water

Part estimates for the minimum wash or sanitation water requirements have been 500 to 1800 ml per man per day, depending on duration and type of mission. Estimates for missions of two or more months duration with moderate water restrictions have run from 1 to 6 gallons per day. In more advanced missions where less restrictive weight limitations may be in force, the water requirements may be expanded to encompass the hygienic aspects of wash water expected for normal earth conditions. It is believed that normal earth hygienic conditions, including washing of clothes, can be maintained easily with 6 to 12 gallons per day; less than 6 gallons could be tolerated without much inconvenience.

Water Purity

The standards for both drinking water and wash water must be considered. Potability standards for drinking water are being developed that will modify existing US Public Health Service and World Health Organization drinking water standards. Tables 9-3 and 9-4 reflect recommended standards for spacecraft use:

Biological quality was of particular concern to the NAS-NRC panel that considered this problem. It was believed strongly that however rigorous preflight testing was, there would still be a water side of spacecraft water recovery systems during takedown operations or adventitious circumstances not encountered during testing. Accordingly, it was the strong recommendation of the panel that any recovery system include a positive sterilizing procedure.

The panel could think of no method except heat treatment, to pasteurization temperatures at least, that is considered acceptable; yet it did not want to exclude other methods of treatment, if they were available or could be devised,

TABLE 9-3

COMPARATIVE PHYSICAL PROPERTIES LIMITS FOR WATER PURITY IN SPACECRAFT

Test	NAS-NRC for Spacecraft	M.P.H.S.
1. Turbidity (Jackson Units)	Not to exceed 10	5
2. Color (Platinum-cobalt units)	Not to exceed 15	15
3. Taste	None objectionable	Same
4. Odor	None objectionable	Maximum threshold No. 3
5. Foaming	Nonpersistent more than 15 sec	---

TABLE 9-4

RECOMMENDED UPPER LIMITS FOR CHEMICAL CONSTITUENTS IN SPACECRAFT WATER SUPPLIES (ppm)

Chemical Constituent	NAS-NRC for Spacecraft	United States Public Health Service	World Health Organization
Arsenic	0.5	0.005	0.2
Barium	2.0	1.0	---
Boron	5.0	---	---
Cadmium	0.05	0.01	0.05
Chemical Oxygen Demand (dichromate method)	100.0	---	---
Chloride	450.0	250.0	350.0
Chromium (hexavalent)	0.5	0.5	0.05
Copper	3.0	1.0	3.0
Fluoride	2.0	1.6 to 3.4	1.5
Lead	0.2	0.05	0.1
Nitrate and Nitrite (as Nitrogen)	10.0	---	---
Nitrate, as No. 3	---	45.0	50.0
Selenium	0.05	0.01	0.05
Silver	0.5	0.05	---
Sulfate	250.0	250.0	250.0
Total Solids	1000.0		

that would be as universally and reliably lethal to all forms of microbial life as heat treatment.

Palatability and aesthetic acceptability are considered very important characteristics for water supplies in space flight. The severe stresses of a long space voyage in closely confined quarters should not be increased by any objectionable appearance or flavor in the water supply. Moreover, lack of adequate quality in these respects will tend to discourage normal intake of water and thus, decrease health and vigor below the optimal level.

RECREATION AND LEISURE TIME

Although certainly not definitive, the following discussion of leisure time use and recreation delineates some of the parameters that have been considered in leisure time use in an isolated environment. Leisure functions, safety constraints, training, and equipment are described herein.

The Purposes of Leisure Time in Confined Habitats

A point was foreseen by Fraser (ref. 20) that seems to be gathering increasing experimental support, namely: "In summary, it is emphasized that whether as part of a terrestrial environment or as applied to long-duration space missions, leisure activity should not be considered merely as a way of filling in time." Eight desirable consequences of leisure-time use in confined habitats are discussed below.

Physical Exercise for Counteracting Behavioral Impairment, Hallucinatory Phenomena, and Disturbance of Electrical Activity in the Brain Induced by Prolonged Group Isolation

Explorers, prisoners, and prisoners of war exposed to brainwashing have reported that self-programmed exercise regimes are of use in counteracting the negative psychological effects of prolonged confinement (refs. 82 and 83). These reports are given strong support in a recent study by Zubek (ref. 84). He found that a group of 18 males in a dome-shaped isolation chamber for one week under substantially reduced sensory input conditions and with a regular exercise regimen as a part of their day showed far less impairment on various tests than did a control group under identical conditions without the exercise regimen.

The exercises were introduced during six 5-min periods each day, and consisted of such things as touching toes, head rotation, and push-ups. The experimental group with exercise regimen showed little impairment during the test week on measures of intellectual functioning, perceptual-motor processing, and electroencephalographic activity, whereas the controls did show impairment on most measures; disturbances of visual and auditory perception after the test were negligible, while the reverse was true for the controls.

Prolonged confinement in a small and isolated habitat could conceivably bring about cognitive and psychomotor impairment of the type measured by Zubek. The isolation and reduction in sensory input would not be as severe but would be more prolonged. Consequently, a regular exercise regimen would seem to be an important addition to the regular schedule of the inhabitants as a safeguard against such impairment.

Physical Exercise for Counteracting Adverse Physiological Effects of Long-Duration Exposure to Zero Gravity

The potential importance of exercise in maintaining proper physiological functioning during prlonged zero-gravity conditions has long been recognized. Maintaining proper physiological functioning includes maintaining skeletal-motor tone, cardiovascular system tone, calcium mobilization, gastrointestinal functioning, and respiratory vital capacity (refs. 85 and 86). Some proposed exercises include isometrics, massages, breathing exercise, dyna-mometer, rubber bungee cord, toe touching, muscle tensing, harness, and pedal ergometer, but the exact requirements and priorities for such exercise schedules only can be determined after prlonged effects of zero gravity on human physiology are better known. Some of these considerations may be relevant to other isolated habitats, particularly those related to development of small and light exercise equipment and to the question of maintenance of adequate tone when access to free volume is highly limited.

Leisure Time for Development and Maintenance of Group Morale and Intragroup Communications

Group morale could make extreme differences in perceived quality of life in any given habitat. The most relevant evidence for the importance of the development of group morale during leisure time would seem to come from reports concerning successful and unsuccessful isolated military and scientific outposts. Shared meals, film watching, and hobbies can become highly important to the men of such outposts. For example, in Thule Air Force Base in Greenland, "To counterbalance the low morale and high 'psycho' rate at Thule, the Air Foce built a hobby shop and stocked it for a variety of interests. Morale went up. An Air Force doctor stationed at Thule said, 'We found that a good hobby is one of the best methods of 'shock' prevention, because anything that will help pass a day at Thule is worth its weight in psychiatric couches.' Other Air Force bases have reported similar occurences." (See ref. 87.)

Leisure Time for Counteracting Feelings of Deindividuation Imposed by Rigid Scheduling and Restricted Personal Freedom in Isolated Habitats

Zimbardo in studies of urban and suburban environments finds that environments allowing little freedom of choice lead to feelings of deindividuation on the part of the inhabitants with subsequent marked increase in acts of social irresponsibility and violence (ref. 88). He also finds that geriatric patients who feel they are in nursing homes by choice show lower mortality rates than those who feel they have been forced there (ref. 89). Much time in isolated habitats will often be devoted to mechanical and routine tasks; this is emphasized dramatically in the report by Serendipidity Associates (ref. 85) on time

allocations for crew members of a Mars-Venus exploratory missions. Leisure time would be a time during the day when some freedom of choice could be permitted. Well-planned leisure-time facilities thereby could allow individual expression of the type that, according to Zimbardo, increases social solidarity and decreases the threat of antisocial behavior.

Leisure Time for Increase in Daily Variety

A key problem in psychological optimization of confined and isolated habitats appears to be increasing the subjective sense of variety in any one day's happenings. When the isolated habitat is compared with the normal habitat, there is a marked difference in variety. The isolated habitat generally has considerably less variety in kinds of sensory inputs (refs. 26 through 28), types of motor responses called for, and available types of social contacts. Generally, this is even more true of rhythmic variations over time than of immediately apparent variations; the isolated habitat immediately evidences considerable restriction in variety of perceivable input and shows particularly small amounts of variation in these inputs over time. Combatting the feelings of monotony built up by such a habitat appears to be a key design constraint. Leisure time is a particularly good time to provide some variety. Microfilmed libraries, taped music and readings, and movie films could help in providing such variety with a minimum weight penalty.

Maintenance of Social Contact with the World and with One's Home

Closely related to the above problem of relieving monotony, channels of communication to the home base for nonmission-oriented interchange would seem feasible and psychologically quite meaningful. One function of such communication would be to give crew members access to the news, current entertainment, and new developments in science, the arts, etc. In addition to increasing topics of conversation between crew members, access to such communications could increase the subjective feeling of variety in day-to-day life. The feasibility of communication with close relatives and friends, possibly using coded communication channels that could not be monitored by most receiving sets, is potentially highly morale boosting and important in increasing the variety of social contacts that a crew member could make during his leisure time.

Constructive Personnel Development and Expanded Education Repertoire

Isolated habitats in which the quality of life is perceived favorably seem to lead to increased demand for reading time and reading complexity (refs. 90 and 91). If such were the case in a given isolated habitat, leisure time could play a particularly valuable role in individual development. If desired, programmed instruction and some variety of modern audiovisual display could be used for crew members wishing to use some part of their leisure time for such constructive purposes.

Leisure Time for Tension-Induced Autonomic Arousal to Return to Basal Levels

Weybrew (ref. 31) hypothesized that some individuals under selected circumstances may, when exposed to successive stressors, fail to recover autonomic

nervous system (ANS) displacement induced by one stressor before a subsequent stressor is imposed. Such individuals may exhibit a "stair-stepping" response sequence to the stressors of a particular type of environment, resulting in chronic autonomic nervous system disequilibrium. He later found (ref. 92) that submariners showing slow autonomic recovery appeared to show poorer adjustment to the submarine environment than did men with quick recovery indexes. At any rate, exercise, recreation, and leisure time appear to increase the time interval between environmental stressors and allow tension-induced autonomic displacement to recover before exposure to new tension-inducing stimuli. Furthermore, acceptance of this as a function of leisure time would suggest that any crew member could be trained before the actual mission to utilize leisure time as a method of allowing autonomic nervous system displacement to return to basal levels.

Safety Constraints

Participation in some types of leisure-time activities may have to be forbid because of safety. For example, wrestling could be a beneficial leisure-time activity as several authors on habitability arrangements for isolated environments have pointed out. However, the possibility of injuring oneself in the limited confines of such habitats should be considered as well as the possible consequence of such injury, even if the changes of such an occurrence are few. Some considerations of safety should be made in planning for leisure time in isolated habitats, depending on the nature of the mission and the likelihood of injury. Note that Start (ref. 93) finds that personally selected leisure-time activities such as sports generally show much higher risk rates than activities engaged in as part of the normal public way of life (such as driving a car, riding in a public airplane, or even being a member of a fighting team during war).

Three Hypotheses Concerning Leisure Time and Habitability

As discussed previously, Weybrew has presented evidence that speed of autonomic recovery after perceived stress is related to success in adapting to the limited environment of the submarine, and has presented a theory that stepwise increases in autonomic arousal caused by inability to return functioning to a basal autonomic level between successive stressors can lead to chronic autonomic disequilibrium. It is predicted that (1) the more an environment brings about chronic ANS disequilibrium without allowing for adequate recovery during leisure time, the lower the environment will score on psychological measures of habitability; (2) the greater the ANS displacement at the beginning of leisure-time periods in confined environments, the less these time periods will be used for constructive leisure-time pursuits; and (3) the less habitable the environment, the less constructive will be the use of leisure-time periods.

A marked difference is apparent in reviewing the literature on isolated environments with respect to leisure-time use. Some environments seem to lead to progressively less constructive use of leisure time. For example, Rohrer

(ref. 94) reports that men planning for leisure-time use at Antarctic stations generally intend to read good books, listen to taped scientific lectures, study a language, or study for promotion; however, leisure-time use disintegrates into reminiscing or telling tall tales. Similarly, crew members of the Ben Franklin Gulf Stream mission reported bringing along worthy books they intended to read but generally used their leisure time for inconsequential and nonconstructive activities.

Reports on leisure-time use in nuclear submarines indicate the opposite trend (refs. 95 and 90). More time was spent with more complex and educational books, and a stronger drive was observed toward advancing and bettering oneself in one's leisure time as the time in the habitat increased. Similarly, Findley, Migler, and Brady (ref. 91) in a study of 151-day inhabitation of an isolated but carefully psychologically programmed environment found an increasing tendency to read.

The difference in leisure-time use in these various isolated habitats may be related to designs that lead to differences in indexes of habitability, or perceived quality of life, in the various situations. That is, Antarctic stations may be relatively low on group morale, daily moods, positive social interchange, and other indicators of habitability, whereas nuclear submarines may be rather high on these indicators. If this theory is correct, chronic autonomic disequilibrium would be less likely to occur and autonomic arousal more readily lowered to base rates on the submarine than in the Antarctic station as currently designed. The reports released on these two types of isolated habitat lend some credence to this theory.

This approach does not consider the degree of ANS displacement that normally occurs in a given habitat, but how the habitat allows for reduction of whatever displacement might occur. In particular, a large difference may exist between (1) the habitat that arouses anxiety or ANS displacement while allowing reduction of the displacement through appropriate tasks undertaken during work time or leisure time, and (2) the habitat arousing anxiety that is not reducible by any work-time tasks leisure-time activities. Also, the amount of ANS displacement present at the beginning of leisure-time activity in an isolated habitat is not a function of how much anxiety is created working in the habitat; it is a function of how much anxiety is created by working or by other factors present in the habitat that cannot be reduced by any work activity.

Premission Training in Optimizing Leisure-Time Use

Research could be conducted to determine whether special physiological training methods should be used prior to a mission to specifically optimize leisure-time use and to optimize perceived habitability in general. A large number of recent studies (reviewed in ref. 96) have shown that people can be trained to control many of their physiologic functions, in particular autonomic nervous functions. Results indicate that people can learn to control electroencephalogram (EEG) rhythms, blood pressure, electromyogram (EMG) levels, heart

rate, electrodermal activity, renal artery functioning, salivation, skin temperature, vasoconstriction, and other physiologic responses (see, for example ref. 46). Results also indicate that subjects can be trained rather rapidly to discriminate and control such functions without external feedback assistance. Both Nowlis (ref. 97) and Budzynski (ref. 25) indicate that six or seven 1-hr sessions will suffice for most subjects in learning to discriminate and control a physiologic process. Although many such studies have been conducted for single-response systems, research in how to teach control over several autonomic processes to the same individual has been sparse. This alternative appears to be the best if the established goal is training people to quickly return autonomic imbalances to normal. Presumably, such training would allow people to tolerate higher amounts of stress without succumbing to autonomic disequilibrium, and would allow them to relax more quickly after tension inducing situations. If Weybrew's theory is correct, it can be predicted that men trained with such control could adapt better to the stresses of an isolated habitat. Using the extension of his theory described above, such individuals would perceive the quality of life in their isolated habitat more favorably and also would use their leisure time more constructively.

Desirable Leisure-Time Equipment for Isolated Habitats

A study by Eddowes (ref. 98) of people imagining themselves on a space journey and asked what kinds of leisure-time activity they would most like to have available indicated the ten most common choices were:

(1) Books

(2) Playing cards

(3) Chess

(4) Musical instruments

(5) Record equipment

(6) Handicraft equipment

(7) Art supplies

(8) Writing supplies

(9) Athletic equipment

(10) Puzzles and games.

Although it is theorized that leisure-time use would be to some extent a function of perceived habitability of the environment and prior training in maximizing the benefits of leisure time in stress inducing environments, Eddowe's list is generally a meaningful one if the hypothetical environment is a supportive and

habitable one. If Zimbardo's theory is correct, members of such a mission should have some free choice in selecting their leisure-time activities. If they choose the same types of equipment as those interviewed by Eddowes, tradeoffs would have to be made for such items as musical instruments and athletic equipment, which may be too heavy and/or bulky, depending on the nature of the isolated environment.

A leisure-time package should be put together, some items of which would be required and others dependent on the choices of the particular crew members involved. Required equipment might include (1) exercise equipment, (2) film projector (fig. 9-5), (3) microfilm projector, (4) tape or record player, and (5) lightweight audiovisual device for educational purposes. Also, part-time access to communications from base concerning news, recent entertainment, etc. and part-time access to private two-way communications with kin and friends could be provided. Other equipment might include a small chess set, selected microfilms, selected motion pictures, selected tapes or records, selected programmed instruction units, selected small musical instruments, writing materials, artistic materials, and other kinds of puzzles, games, and hobbies. Leisure-time constraints would affect design of the habitat space, especially the dining area, the exercise area, whatever private area existed for each crewman, and the communication areas. If the habitat were to be in a zero-gravity condition for any length of time, appropriate modification of at least some of the leisure equipment would be necessary and some new games might be designed to take advantage of the condition. In particular, interesting and absorbing computer games could be employed (ref. 99). The projection and programming systems for such leisure activities also could include directions for equipment, repair, and learning programs to enhance or maintain requisite skills and knowledge relevant to mission operations and mission success.

EXERCISE CONSIDERATIONS

Exercise is essential to the maintenance of neuromuscular tone, cardiovascular condition, and normal mineral metabolism (maintenance of bone). To maintain physiologic tone, the body must be exercised at work loads that will force heart rates of 140 to 160 beats/min for at least 10 min. The best kinds of exercise equipment to use for this purpose are those that require total body involvement for proper use. The bicycle ergometer developed for NASA/MSC for use in the M050 experiment and the U.S. Air Force total body exerciser developed for the Manned Orbiting Laboratory program are the best examples. The ergometer is the preferred exerciser.

Exercise immediately after a sleep period will benefit all crew members by minimizing any pooling of blood that has occurred during that period of inactivity. Since it would not be feasible to have 12 bicycle ergometers, additional exercise techniques and equipment should be included. A list of potential supplementary techniques and equipment is given below. Each crew member should be required to exercise a minimum of twice, and preferably three times, each day. The ergometer exercise period would consist of a 5-min warmup period of gradually increasing pedal load until the predetermined workload

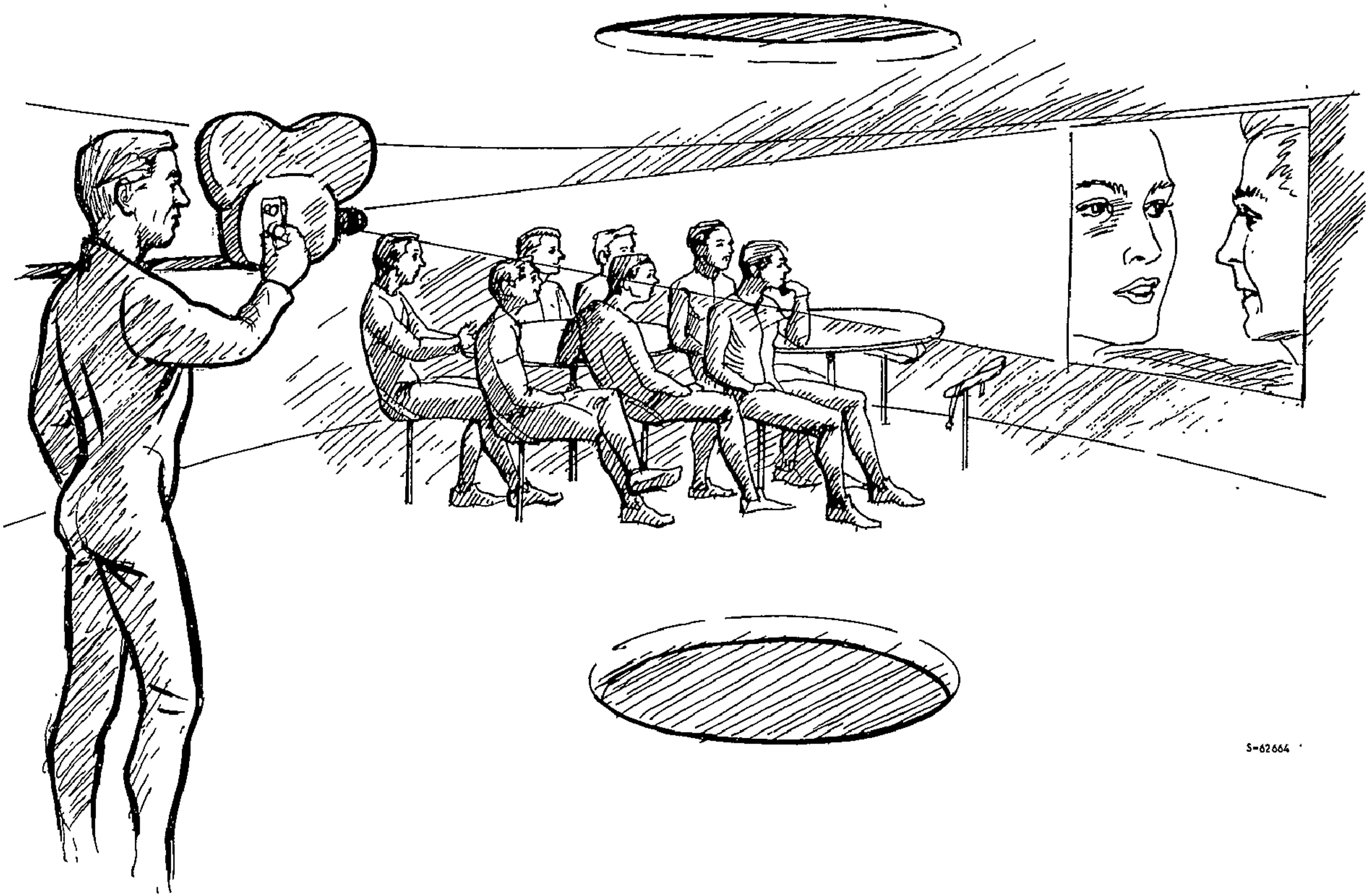


Figure 9-5. Film Projection in Wardroom

necessary to produce a heart rate of 140 to 160 beats/min is reached. The crew member should then continue to exercise for 10 min at that work load. The ergometer and associated medical equipment can be used to evaluate the physiologic status of the crew members by having them perform a modified Balke exercise test (measurement of oxygen consumption during programmed exercise).

Each crew member will probably choose a supplementary exercise regime to meet his needs of body enhancement and to work off excess energies (frustrations). Techniques and equipment that might be used include:

(1) A two-handled bungee cord for exercising arms, legs, shoulders, back, and buttocks.

(2) Isometric exercises--whole body toning.

(3) Massage--to stimulate circulation. Two or more of the crew could be instructed in the techniques.

(4) Breathing exercises--to maintain the chest and abdominal musculature.

(5) Spring hand-grip dynamometer--for hand and arm muscle maintenance.

(6) Muscle tensing--whole body toning.

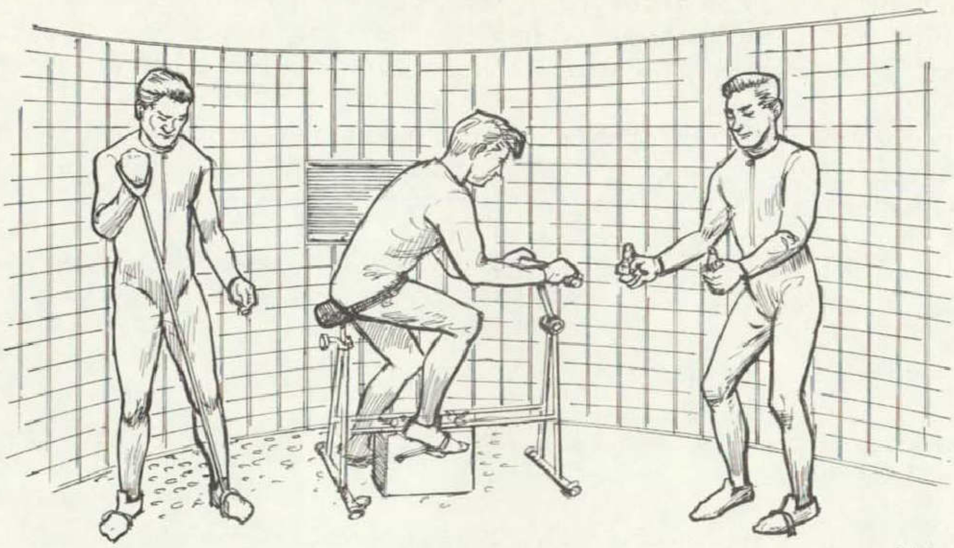
(7) Restraining harness in sleeping bag--used by straining against the harness in different directions.

Exercise will be performed in the wardroom and in the individual sleeping areas. At least two ergometers should be available in the wardroom or in a laboratory area (such as shown in fig. 9-6).

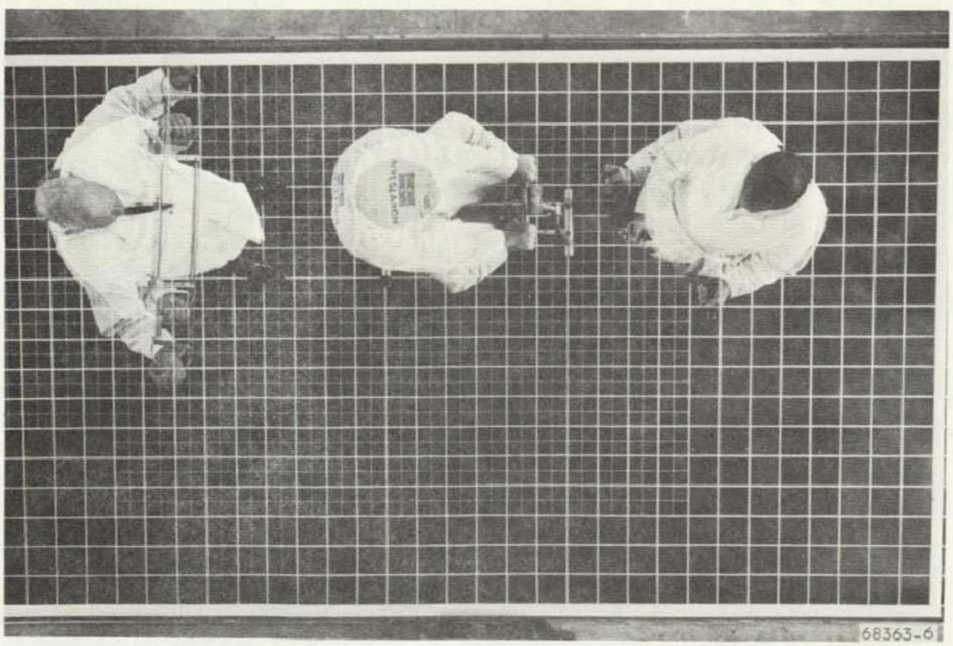
Space permitting, there are two important reasons for a separate exercise area. First, the wardroom does not have to be changed over to an exercise facility, thus eliminating this manual chore. The wardroom is then free for eating, recreation, and assemblies, all of which require little furniture moving. Secondly, if the wardroom is separate, adverse odors usually associated with a gym are not a part of the eating place. Because of these considerations, the exercise area should be separate from the wardroom if at all possible. Exercise is an absolute necessity, and adequate ground training and baseline data acquisition are essential to make it serve its purposes.

ASSEMBLY CONSIDERATIONS

Space must be provided for assembling the entire crew (12 men) for relatively short duration meetings. An additional 12 men are to be included as the relief crew boards the craft and information is exchanged. Design requirements are for a total of 24 men assembled in the wardroom because this is the largest available room.



a. TYPICAL EXERCISE ACTIVITIES



b. VOLUME REQUIRED FOR SUBJECTS TO EXERCISE F-12837

Figure 9-6. Typical Exercise Area and Activities

Anticipated crew assemblies held in this area will be for information dissemination of interest to all, including operational plans, duties, assignments, scientific achievements, and accomplishments. Seating and restraints for those attending should be comfortable and oriented for audiovisual reception of information (fig. 9-7). This figure shows one crew seated around the tables in the normal dining arrangement with chairs rotated to face the speaker. The relief crew is standing around the walls. Local restraints would be provided for holding them in place for the short duration of the assembly (15 to 30 min). Detailed information can be exchanged by breaking into small groups to exchange pertinent takeover information. An emergency exit should be provided because this is the only place where both crews could be trapped if an emergency should arise. Large doors or hatchways will improve traffic flow into and out of this area and reduce queuing.

Visual aids in the form of both movie and still projectors should be built in for easy use without assembling and taking down projectors each time. An overhead-type projector will be useful for the presentation of spontaneous information that can be changed at will or stored if needed.

Lighting of the interior should be controllable from the speaker's location so that the best lighting can be selected for the type of presentation. An audio system for the projectors and the speaker should be designed to provide good fidelity over the entire room.

Layouts were made showing 12 men seated and 12 men standing with space for 2 men to pass in the main traffic areas (fig 9-8). Passageways that have reduced traffic are wide for single passage. The version shown in fig. 9-8 was formed into a pie-shaped segment for use in the mockup, and it was determined to be adequate. A larger or ideal version is shown in fig. 9-9; this area allows enough clearance for two members to pass between all seated members and the walls. Although this is an ideal arrangement for trafficability, the area will not fit into a 33-ft spacecraft with a center tube between levels. Also this plan is more applicable to large space stations with artificial gravity that requires walking instead of free-flight mobility.

Volume required for the wardroom becomes primarily a matter of traffic flow and table configuration. Table configurations have an effect on crew morale and social interactions. During Tektite II, there were many complaints about the table and the lack of adequate aisle space. The table was approximately 48-in.-dia with 14-in. aisle clearance on each side to the bunk. Although the table size was adequate, this aisle space was judged to be totally inadequate. Sections of the table that could be folded down to increase the aisle space were not often used. Social interactions at tables have evoked the interest and curiosity of research personnel. Osmond and Sommer's work (as described by E. T. Hall) was concerned with the relationship of furniture to conservations. It was believed that some spaces were more sociofugal (keeping people apart) than sociopetal (bringing people together). Using a standard 36-in. by 72-in. table for six people, fifty experimental observed sessions were conducted with the following results.

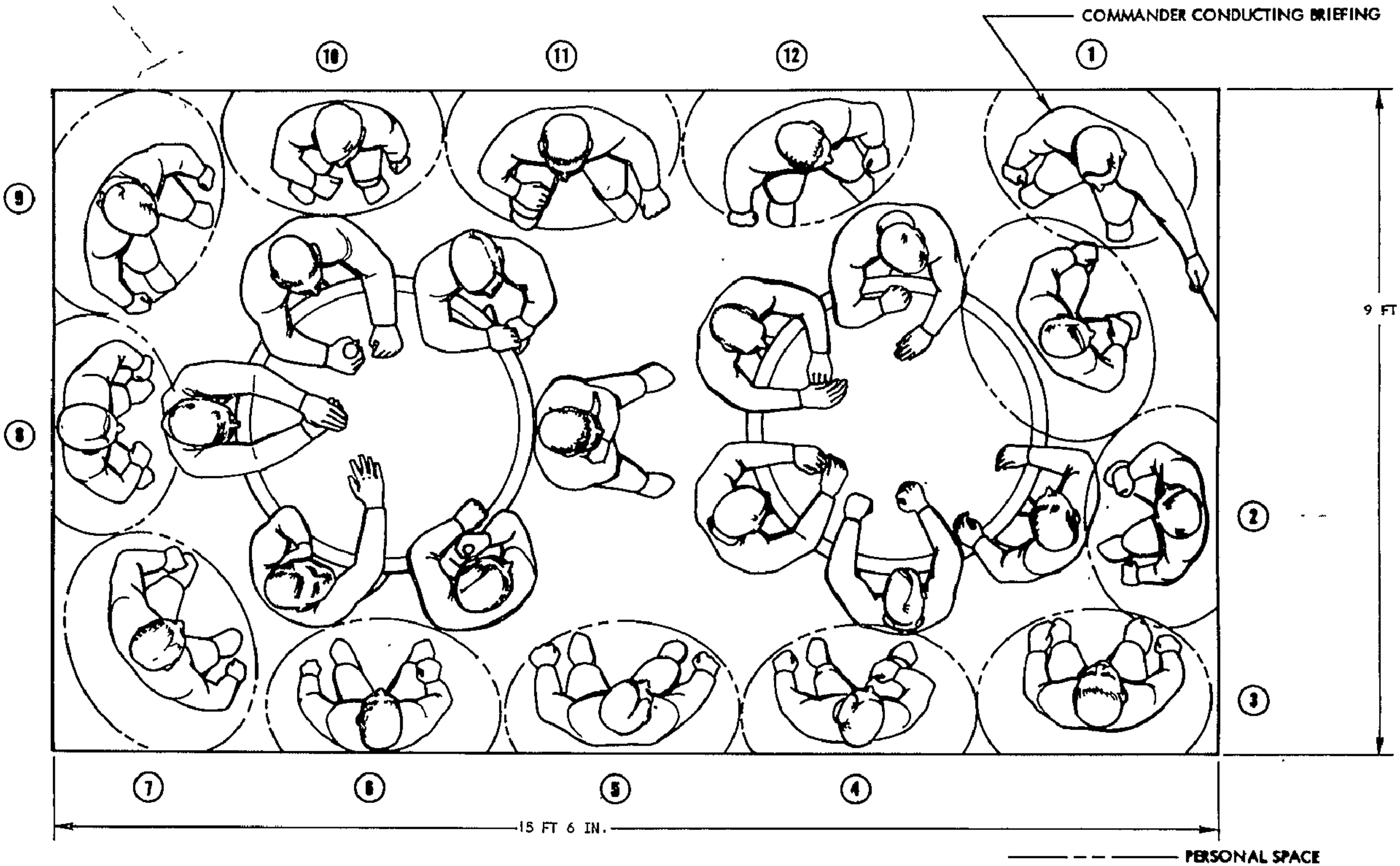


Figure 9-7. Wardroom Showing Two Crews (24 Men) Assembled for a Briefing

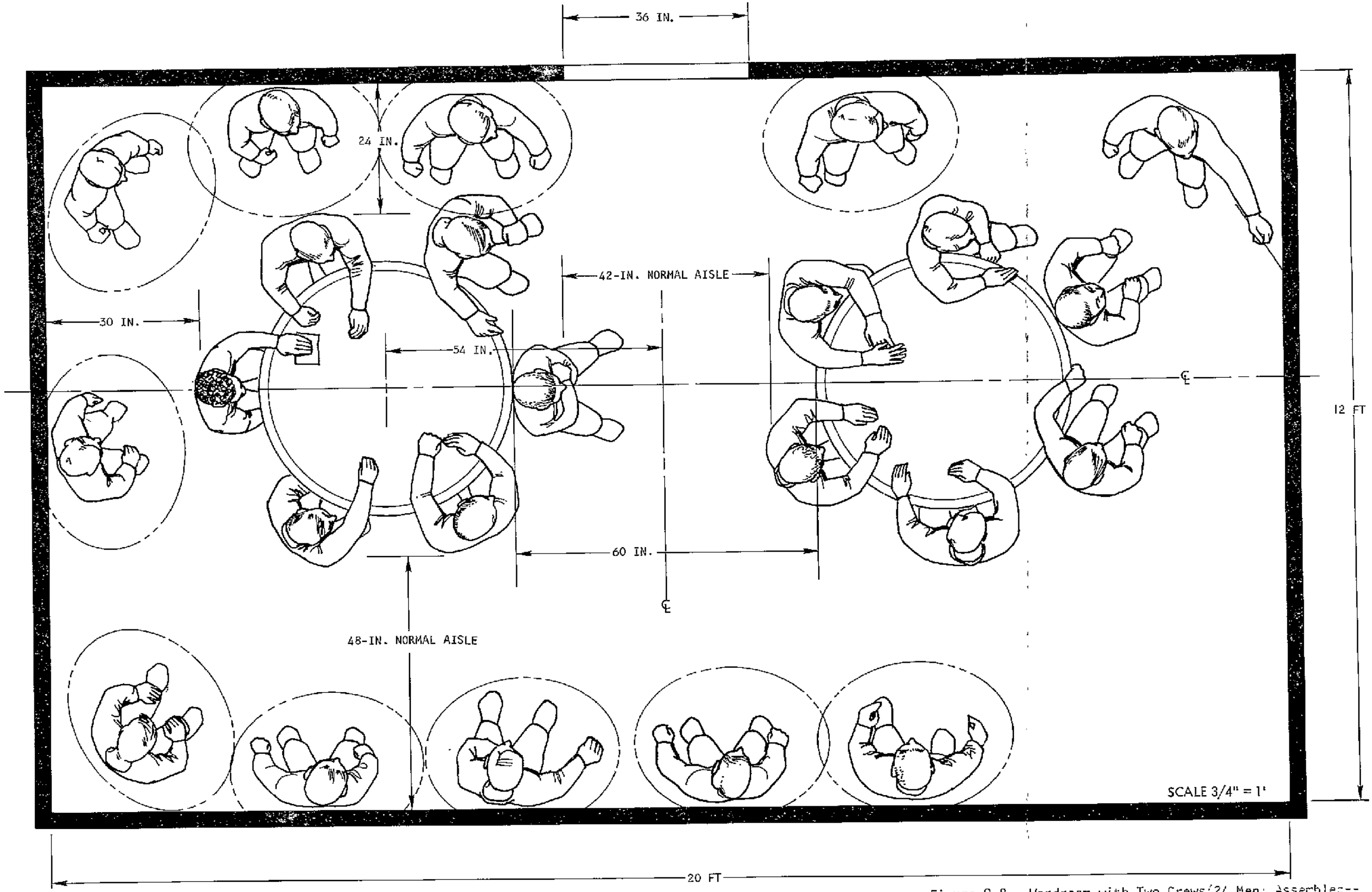


Figure 9-8. Wardroom with Two Crews (24 Men; Assembled--
Area = 235 Sq Ft, Volume = 1500 Cu Ft

FOLDOUT FRAME 1

FOLDOUT FRAME 2

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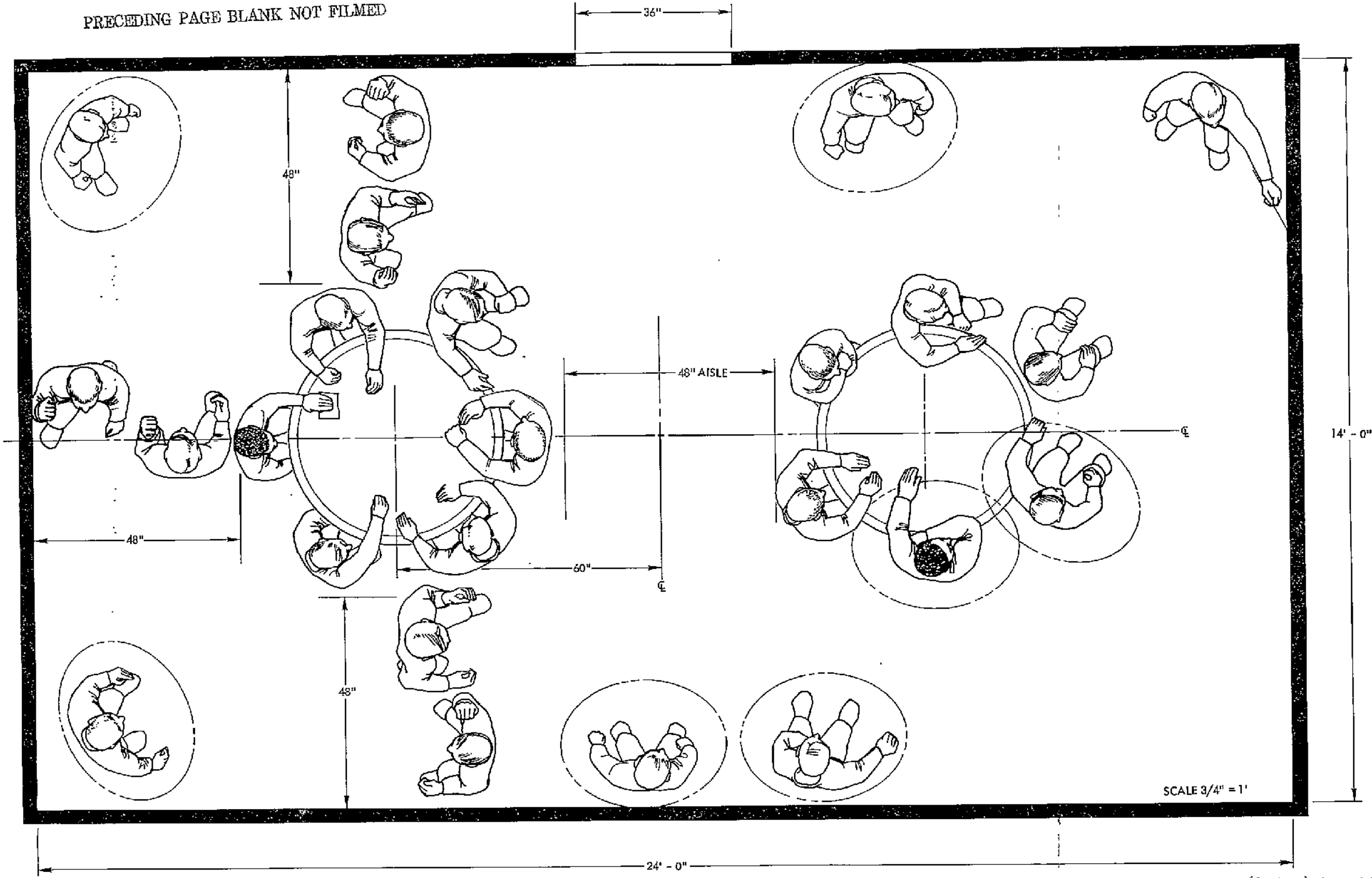
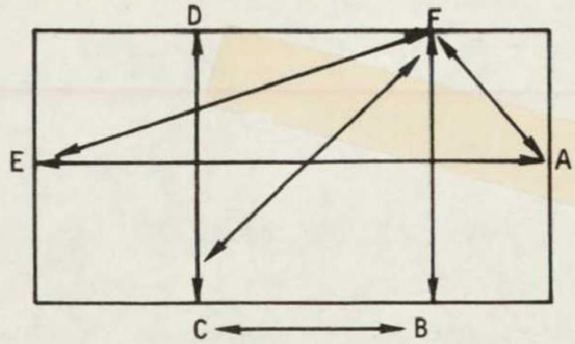


Figure 9-9. Wardroom with Two Crews (24 Men) Assembled--Area = 336 Sq Ft, Volume = 2100 Cu Ft

FOLDOUT FRAME 1

FOLDOUT FRAME 2



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F to A (across corner) conservations were twice as frequent as C to B (side by side), and C to B conservations were three times as frequent as C to D (across table).

Small square tables were substituted and the number of conversations were doubled. Conclusions drawn from these observations, which were made in a hospital situation, are not universally applicable and show only that across-the-corner right-angle seating is conducive to conversation of certain types between persons in certain relationships and in very restricted cultural settings. What is desirable is flexibility and congruence between design and function so that there is a variety of spaces, and people can be involved, or not, as the occasion and mood demand.

A design solution to this situation appears to be tables that are circular in shape. Circular tables will provide the best compromise of seating for conversation, while making the best use of space. However, this may not be the best arrangement if extreme cultural differences exist within the crew. Another alternative would provide for flexibility to change the shape of the table as habituation progresses or other personnel differences surface. That items such as the shape of a table are important in group dynamics is evidenced by the problems encountered in incidents such as the Paris peace talks where the selection of a table in size, shape, and seating arrangements became quite lengthy.

The hypothesized traffic flow patterns shown in fig. 9-1 and 9-2 were evaluated by using full scale mocked up equipment placed on a grid 9 ft wide and 15 ft 6 in. long. The grid was subdivided into 6 in. by 6 in. squares. Paths through the dining area were recorded by subjects carrying a light while performing the simulated motions of dining.

The first plan is shown in fig. 9-10. The crew members enter the dining area, pick up their food, prepare the food, eat, deposit debris, and exit. As anticipated, the high density areas are the food pick up and food perparation areas that are built into the walls. A smoother traffic flow with an alternative wardroom layout is shown in fig. 9-11. In this configuration, the crew members enter, take their seats, eat, deposit debris, and exit. By comparing figs. 9-10 and 9-11, it is shown that the food storage and preparation device in the second plan reduces travel distance, saves time, and reduces volume.

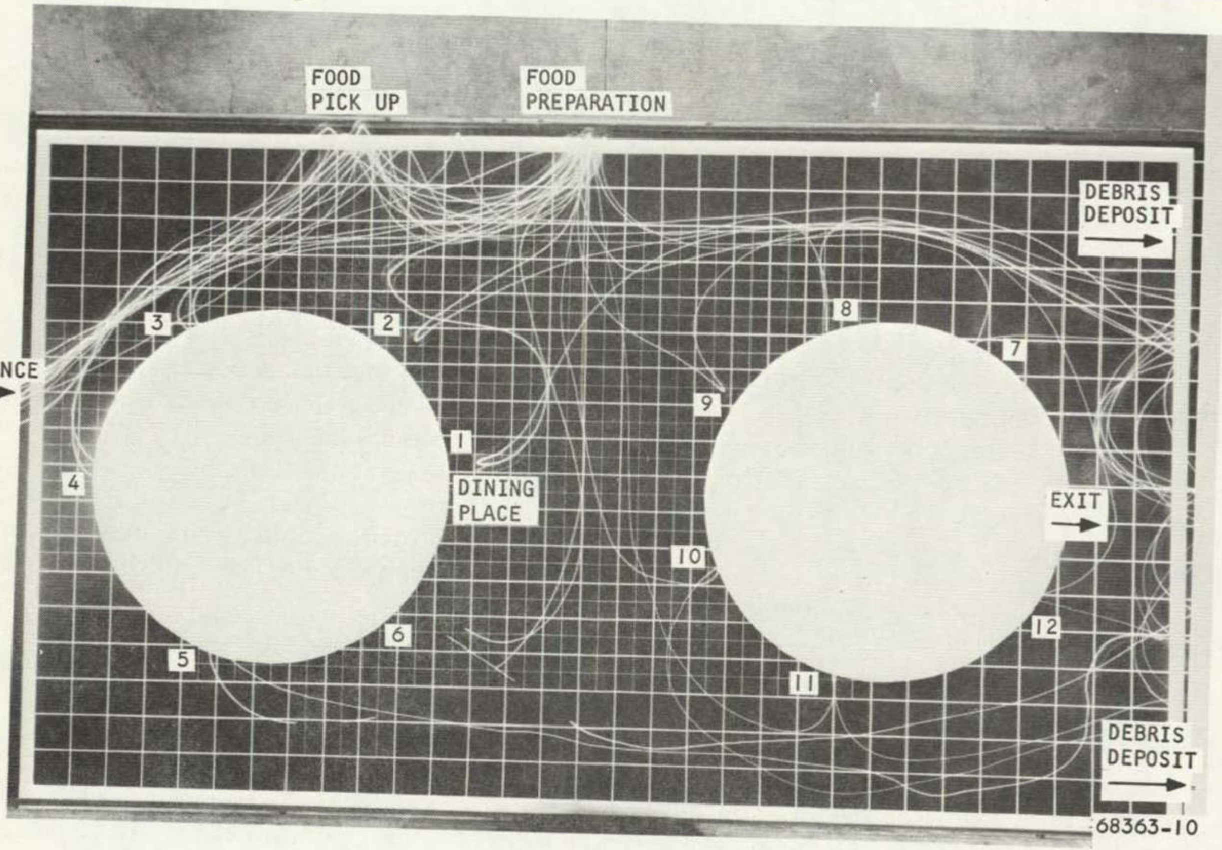

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Figure 9-10. Traffic Flow Through Dining Area for 12 Man Crew (First Plan)

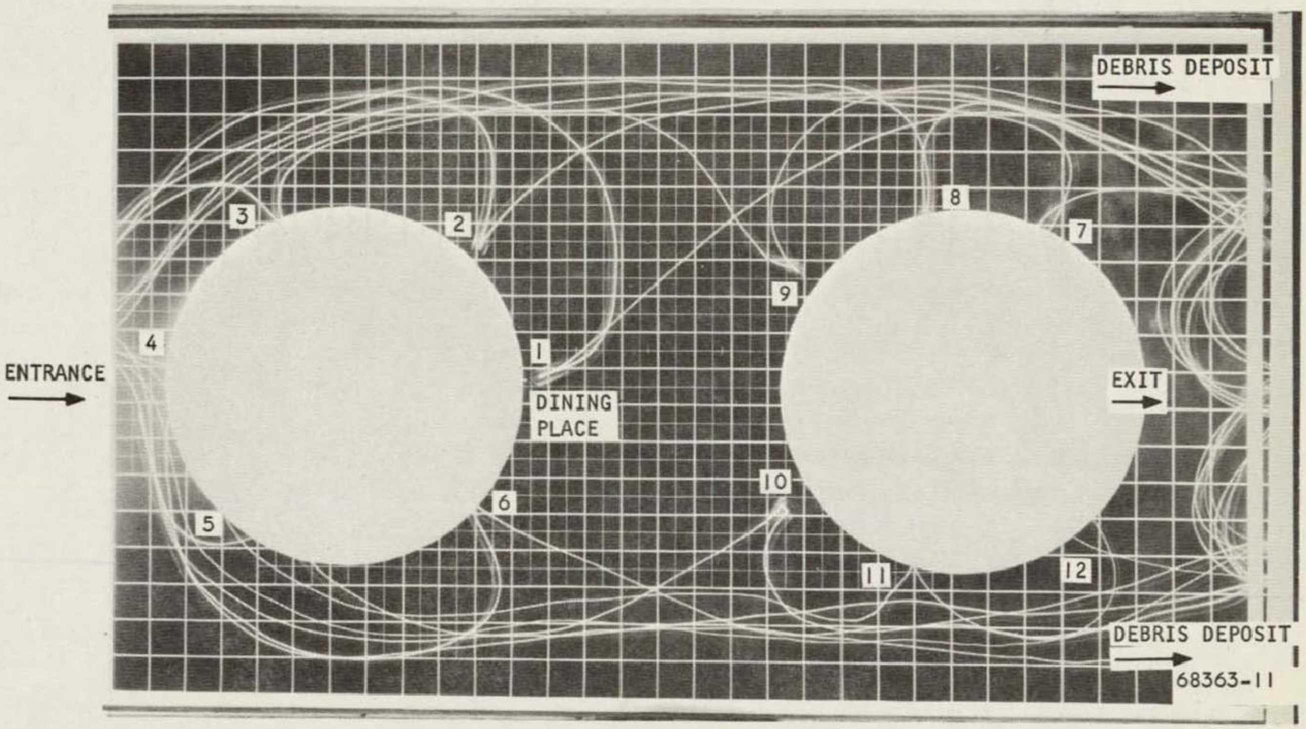

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Figure 9-11. Traffic Flow Through Dining Area for 12 Man Crew (Second Plan)

Additional volume requirements for dining are documented in fig. 9-12, which shows the area required for 6 men seated at a round table, In fig. 9-13, round and rectangular tables with a 12-man crew at each are compared. This comparison shows the volume that can be saved by using round tables.

WARDROOM VOLUME CONSIDERATIONS

Wardroom volume is determined by all equipment, personel, and space that will allow accomplishment of tasks defined by the functions. Although this design approach satisfies short-duration mission requirements, design for long-duration missions must include the space modulators (described in Section 3) if crew efficiency is to be maintained.

The wardroom is a multi-purpose space that is used for eating, recreation, exercise, and assembly. Because of this multi-purpose use, equipment used for one activity such as eating must be moved or relocated to provide space for a another activity such as exercise. Some tasks will require little or no equipment change, such as using the dining tables for viewing movies. Specific mission planning can allocate crew member activities to specific periods of time, which will result in efficient use of the wardroom volume. For instance, if the entire crew exercised simultaneously, a very large volume would be required. By scheduling only three or four members to exercise at the same time, the amount of equipment and volume necessary for this activity is greatly reduced.

A study was conducted to determine optimum use of facilities for eating needs: two round tables, one round table, or one rectangular table. The results of the study are shown in fig. 9-14 and listed in table 9-5.

Associated with the basic design concept are volumetric constraints that modify the usable configurations. One constraint is the ceiling height, which has been fixed at 6.5 ft to allow both 5th and 95th-percentile crew members to reach from floor to ceiling for compression walking in zero-g conditions. Another constraint is the fixed width of the capsule, which allows a usable inside diameter of 30 ft and a 10-ft-dia tunnel. This fixes the wardroom width at 10 ft, and the area and volume of one level at 629 sq ft and 4088.5 cu ft, respectively.

Volumes required to accommodate two traffic patterns have been studied to determine applicability. The two basic configurations have enough area and associated wardroom volume to accommodate twelve crew members simultaneously. In configuration A two men can pass abreast, and in configuration B, only one man can pass by the table. Another consideration is that during crew changeover periods, it is necessary to provide adequate room for 24 crew members to assemble.

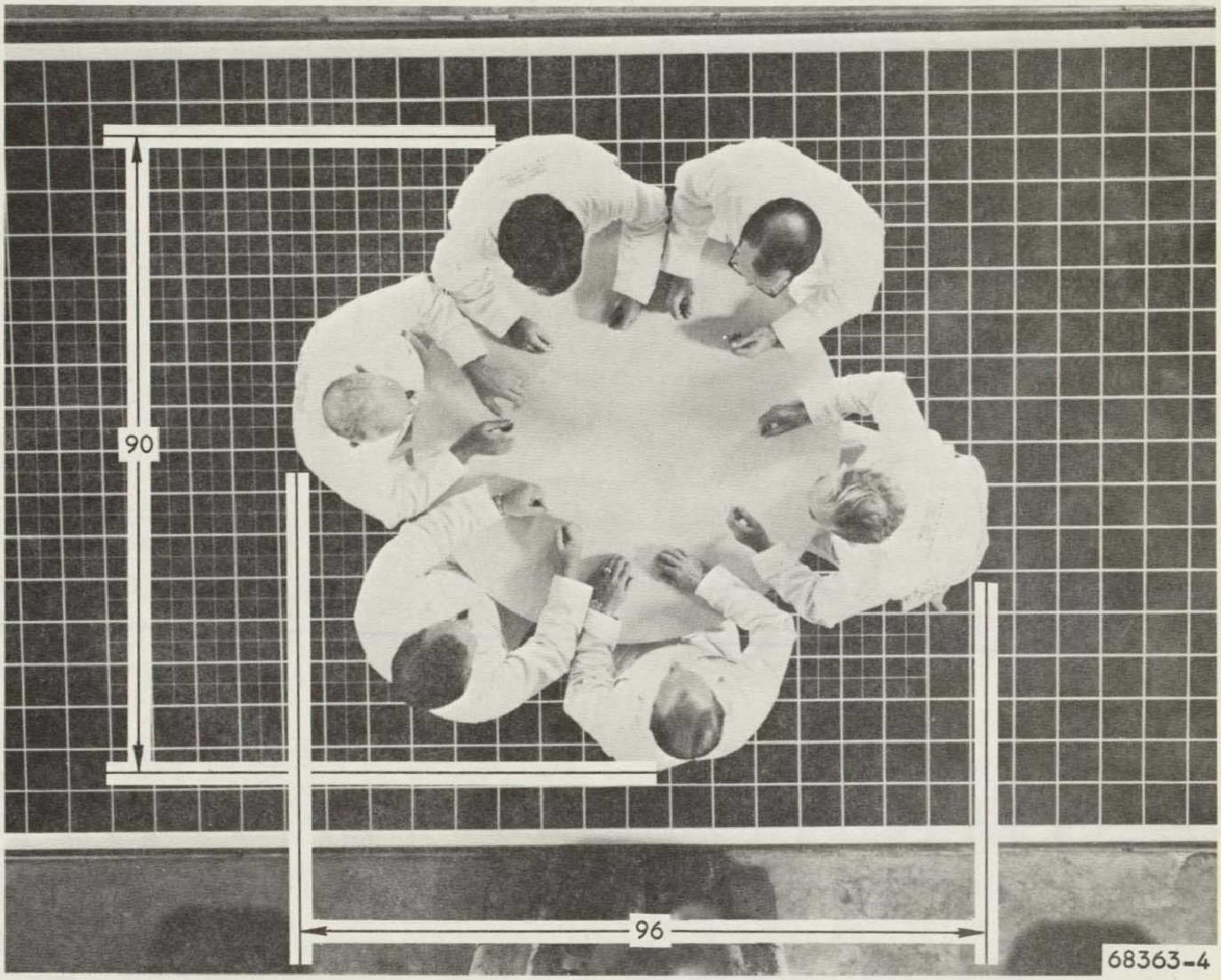

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Figure 9-12. Seating Area for 6 Men at Round Table

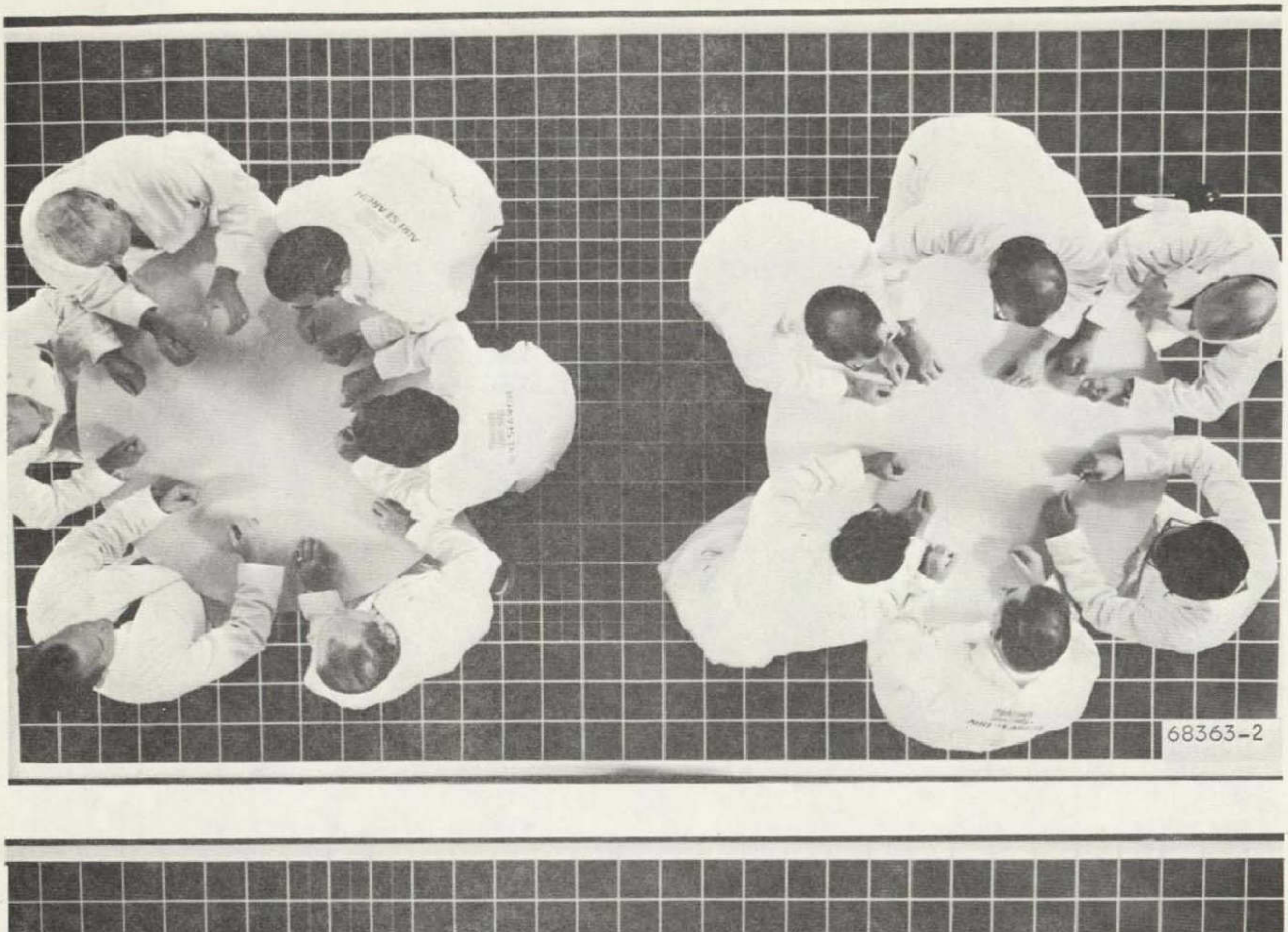

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Figure 9-13. Spatial Comparison of Round vs Rectangular Tables

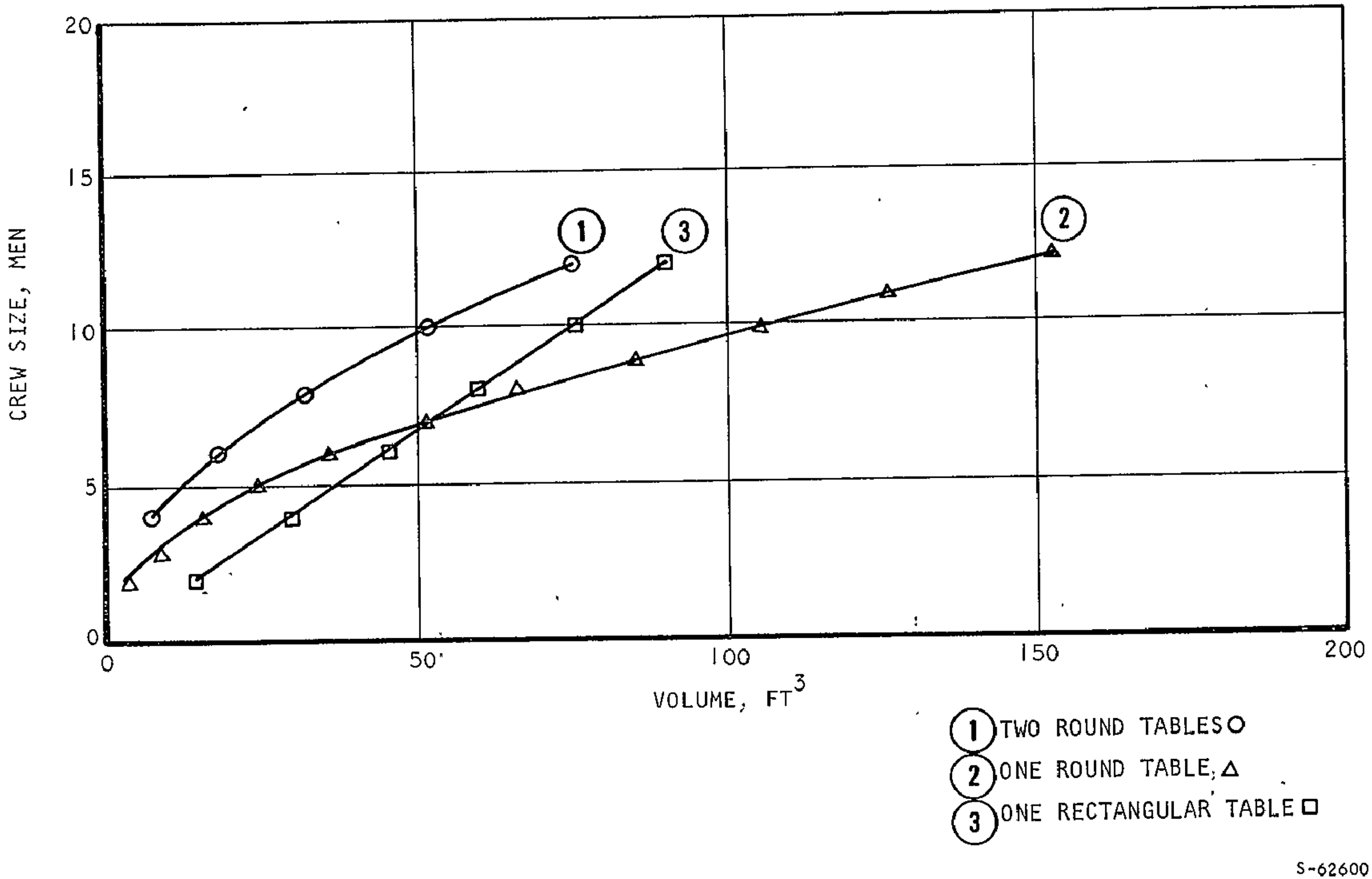


Figure 9-14. Table Study Results

TABLE 9-5

TABLE CONFIGURATION TRADEOFF MATRIX

No. Crewmen	One Rectangular Table		One Round Table			Two Round Tables		
	Volume (ft^3)	Area (ft^2)	Volume (ft^3)	Area (ft^2)	Diameter (ft-in.)	Volume (ft^3)	Area (ft^2)	Diameter (ft-in)
1	-	-	-	-	-	-	-	-
2	15	5	-	-	-	-	-	-
3	30	10	-	-	-	-	-	-
4	30	10	-	-	-	-	-	-
5	45	15	26.3	8.78	3-4	-	-	-
6	45	15	37.8	12.58	4-0	-	-	-
7	60	20	51.5	17.18	4-8	-	-	-
8	60	20	67.2	22.40	5-4	-	-	-
9	75	25	85.1	28.40	6-0	52.6	17.56	3-4
10	75	25	105.8	35.20	6-8	52.6	17.56	3-4
11	90	30	127.1	42.49	7-4	75.6	25.16	4-0
12	90	30	151.2	50.50	8-0	75.6	25.16	4-0

Table Height = 3 ft
Round Table Arc length per man = 2 ft 1 in.
Round Table Chord length per man = 2 ft
Minimum allowable diameter for table = 3 ft 3 in.
Width required for rectangular table = 2 ft 6 in.

The dimensional analysis necessary to determine areas for configurations A and B is presented in fig. 9-15; there is no specific consideration given to spacecraft shape. Dimensions for configurations A and B are shown as $\frac{X}{Y}$, with the X representing the configuration A dimension and Y the configuration B dimension. Where only one number appears, it applies to both configurations.

$$\text{AREA A} = \pi\left(\frac{14.3}{2}\right)^2 = 160.5 \text{ ft}^2$$

$$\text{AREA B} = \pi\left(\frac{11.3}{2}\right)^2 = 100.2 \text{ ft}^2$$

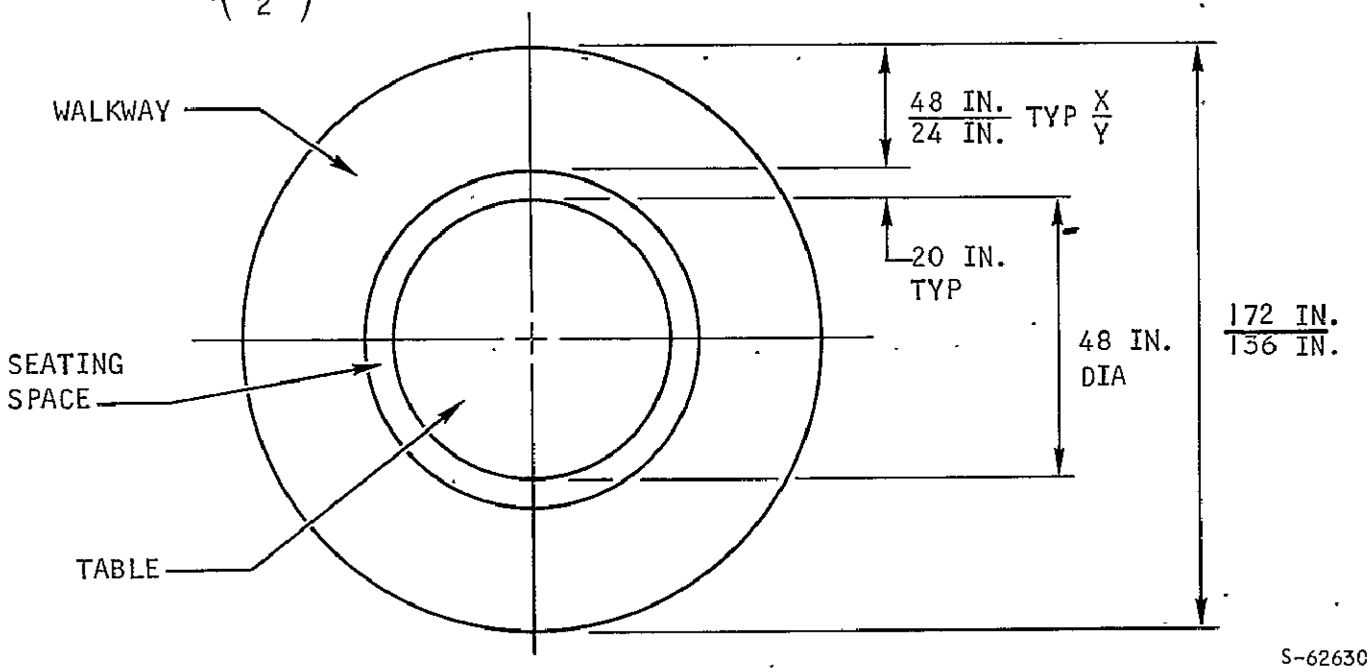


Figure 9-15. Area Requirement for One Table and Six Crewmembers for Configurations A and B

Ideally, the area requirements of configurations A and B are 160.5 sq ft and 100.2 sq ft, respectively. To determine area requirements for larger crews than 6, these area requirement circles can be overlapped as shown in fig. 9-16.

The areas also can be layed out with centers A and B on a radius from the spacecraft center, thus providing an area segment. The spacecraft configuration of a 30-ft usable diameter and a 10-ft center tunnel constrains the wardroom width configuration to 10 ft. This constraint requires redefinition of a configuration to replace configurations A and B.

The new configuration will consist of adequate room for one man to pass sideways around the wall and two men to pass between the two tables with persons

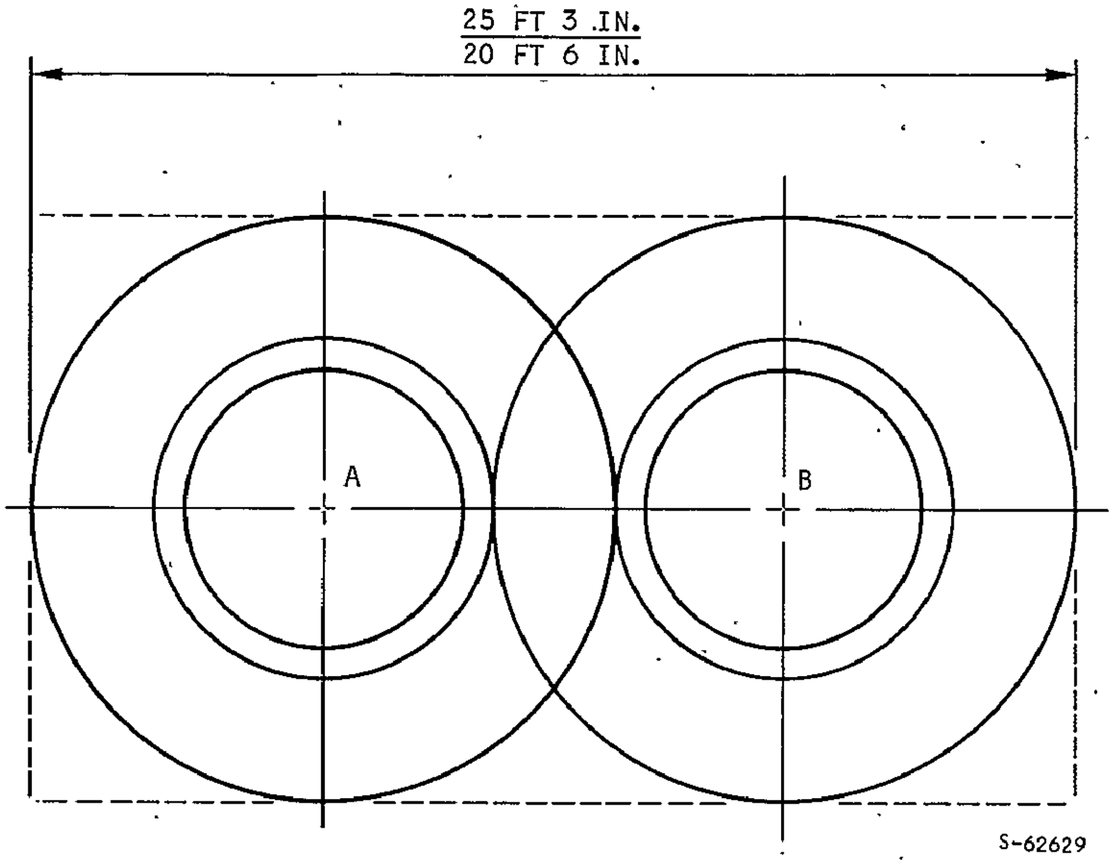


Figure 9-16. Area Requirements for Seating Larger Crews

seated at the table, a layout of which is shown in fig. 9-17. The angular segment requirement for this configuration is represented by the following equation (crew sizes of 5 or greater required):

$$\beta_T = 83 \text{ deg} + \left[(T-1) \quad 2 \arcsin \frac{D_T + 40}{240} \right]$$

where T = No. of tables being used, and

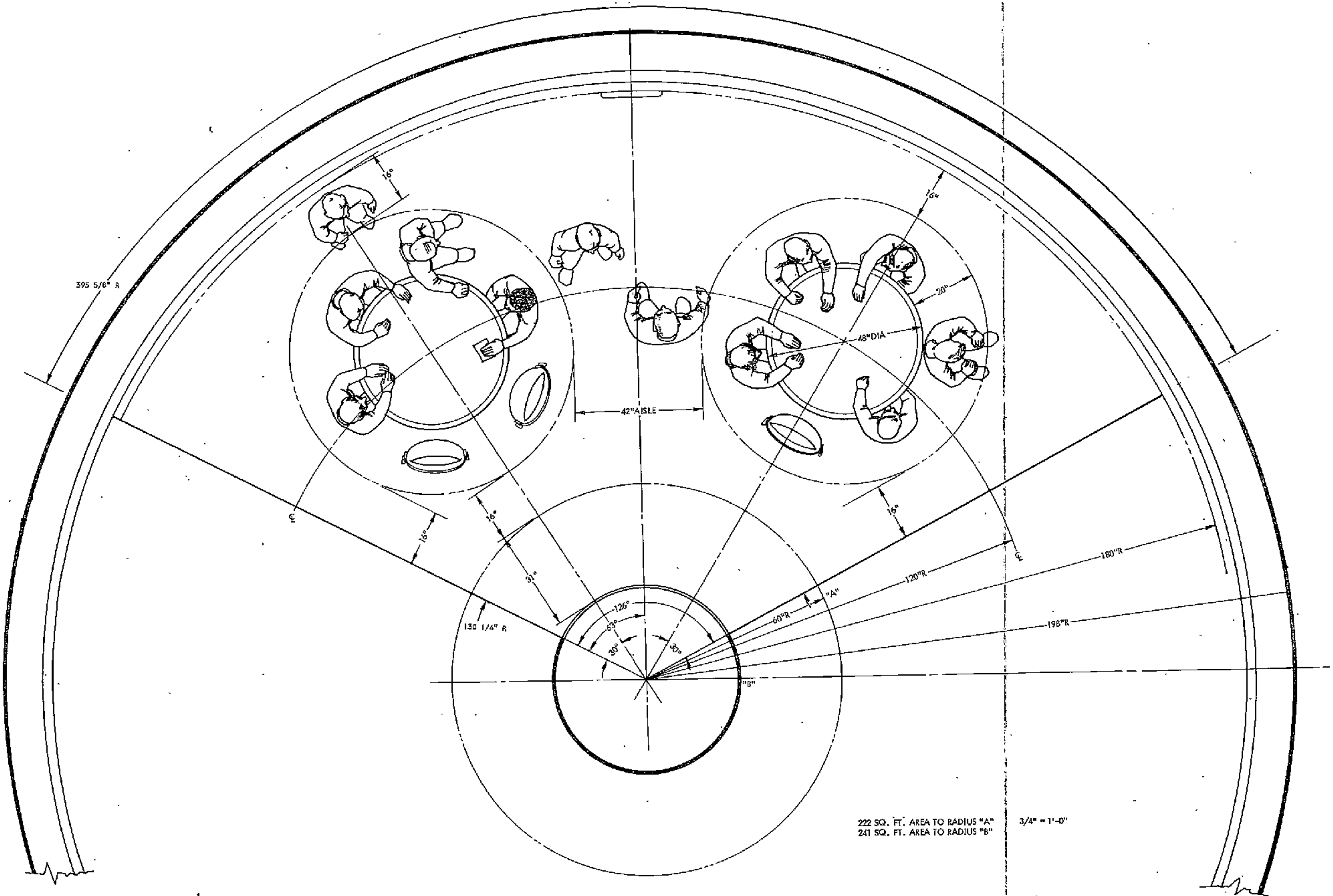
D_T = Diameter of table in inches. This is defined as 8n,

where n = Even No. of crew members seated at one table.

The volume of this segment is represented by the following equation:

$$V_T = (6.5) \left(\frac{\beta_T}{360} \right) (629)$$

$$V_T \leq 4088.5 \text{ ft}^3$$



FOLDOUT FRAME 1

Figure 9-17. Wardroom Layout in a 33-Ft Dia. Spacecraft

FOLDOUT FRAME 2

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Recommended wardroom sizes are shown in table 9-6. A crew of 12 men shows an angular segment of 126 deg containing a volume of 1430 cu ft for a fixed ceiling height of 6-ft 6-in.

TABLE 9-6

VOLUME MATRIX

Crew Size, Men	Table Dimensions, ft	No. of Tables	β_T, deg	V_T, cu ft
1				
2	2.0 by 2.5	1	83	942
3	4.0 by 2.5	1	83	942
4	4.0 by 2.5	1	83	942
5	3.33 dia	1	83	942
6	4.00 dia	1	83	942
7	4.66 dia	1	83	942
8	5.33 dia	1	83	942
9	3.33 dia	2	122	1385
10	3.33 dia	2	122	1385
11	4.00 dia	2	126	1430
12	4.00 dia	2	126	1430

FOOD PREPARATION TIME LINE

Time can be saved for other assigned duties by having the food prepared for the entire crew by one member. (See fig. 9-18.) Queuing problems arise that depend upon the length of time required to prepare the food. Dehydrated foods requiring liquid injection are perhaps the easiest and quickest to prepare. Precooked frozen meals or bite-sized chunks requiring heat from rapid penetration sources such as IR ranges will require more preparation time. The time line shows a saving of 6 min per man by having the food prepared in advance.

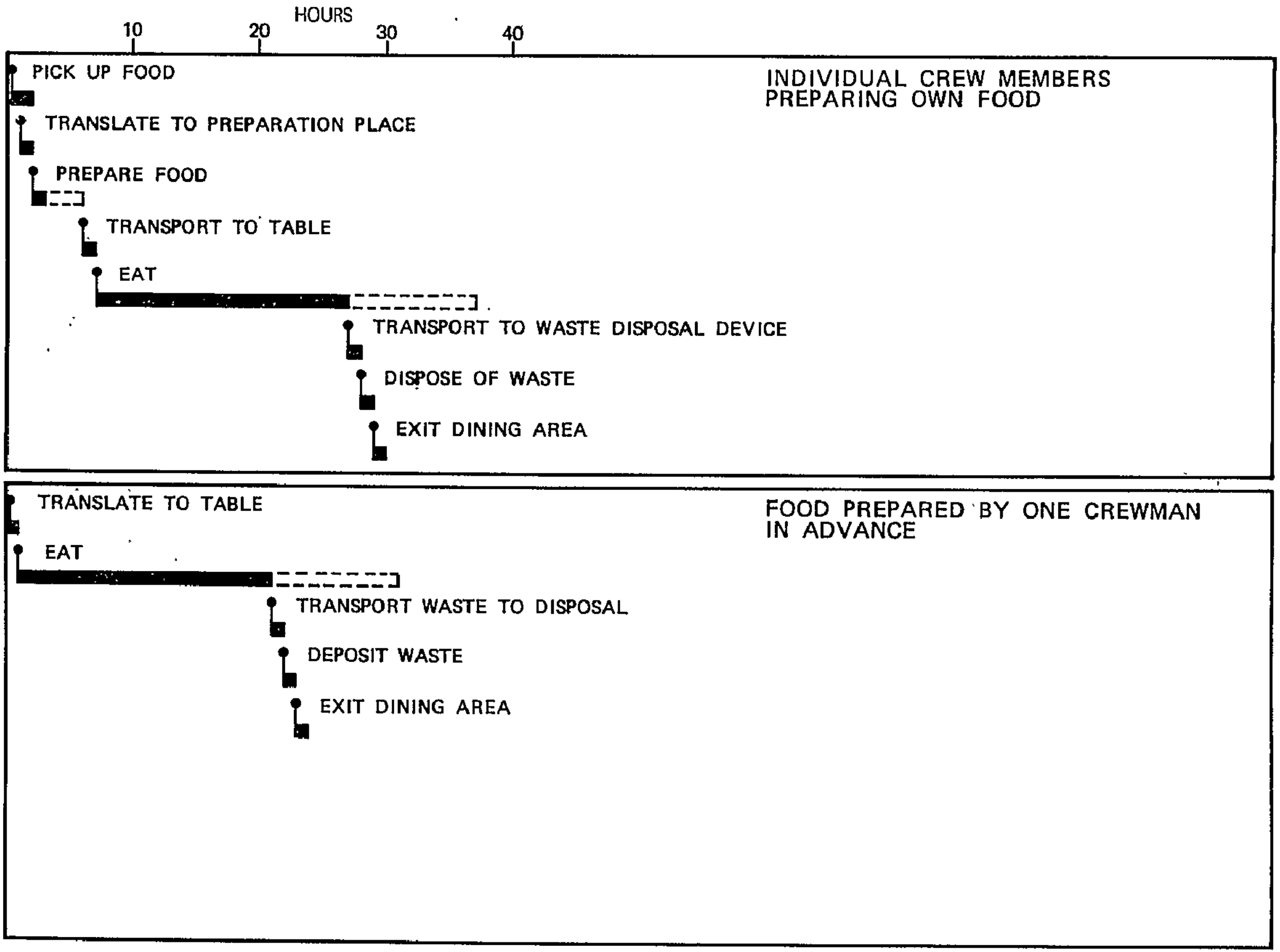

Figure 9-18. Food Preparation and Consumption Time Line

This amounts to a saving of crew time as shown below of approximately 42 min per meal, or slightly more than 2 hr per day.

$$
\begin{aligned}
6 \text{ min} \times 12 \text{ men} &= 72 \text{ min} \\
&\underline{-38 \text{ min}} \text{ cook time} \\
&42 \text{ min}
\end{aligned}
$$

If the tables are not to serve as multi-function devices, such as game tables or medical facilities, designs can include the functions of food storage and preparation in one device. Food wastes should be deposited in a remote container to prevent bacteria from contaminating the remaining food supply.

SEATING RESTRAINTS

Seating devices function as (1) an upright support for eating and working at table height, and (2) a lounge for relaxation. In zero-g, both types should be made of soft flexible material with restraint straps that fasten with velcro. The ribbon restraint (fig. 9-19) is made from a flat sheet of flexible material that meets applicable specifications and that is formed into a circle and attached to a support. The support can be made from aluminum tubing or fiberglass. A quick-release latch mechanism is built into the post with the release located under the seat. This seating arrangement is applicable for not only zero-g but for varying g conditions up to and including one-g. An alternate zero-g seating device is the tubular seating restraint shown in fig. 9-20. It is lightweight and flexible; the seat is a tube similar to a bicycle inner tube. Restraint straps are attached to opposite sides of the circle with quick-release fasteners. Structurally, this version would require additional support if it were used in any condition other than zero-g. Both versions are easily stacked for conserving space during storage.

Conventional seating (fig. 9-21) has the advantage of being useful under both partial-g and zero-g conditions. Seating devices that are designed exclusively for zero-g will not be readily adaptable to other gravity conditions.

MOCKUP EVALUATION

Mockups were built of an absolute minimum wardroom (9 ft by 5 ft 6 in.) in the shape of a rectangle, and two round tables and 12 chairs were placed inside (fig. 9-22). Aisle space is provided for one person only, and passing cannot be accomplished except in the corners where free-floating traversing can be accomplished. Although large enough for seating the crew at one time, this room "feels" too small and confining. Using the volumetric data developed in this report, an area of 235 sq ft was designed; this allows enough aisle space for two men to pass shoulder-to-shoulder in the main traffic paths. As shown in fig. 9-23, two men can pass between the seats and the entrance cylinder. One

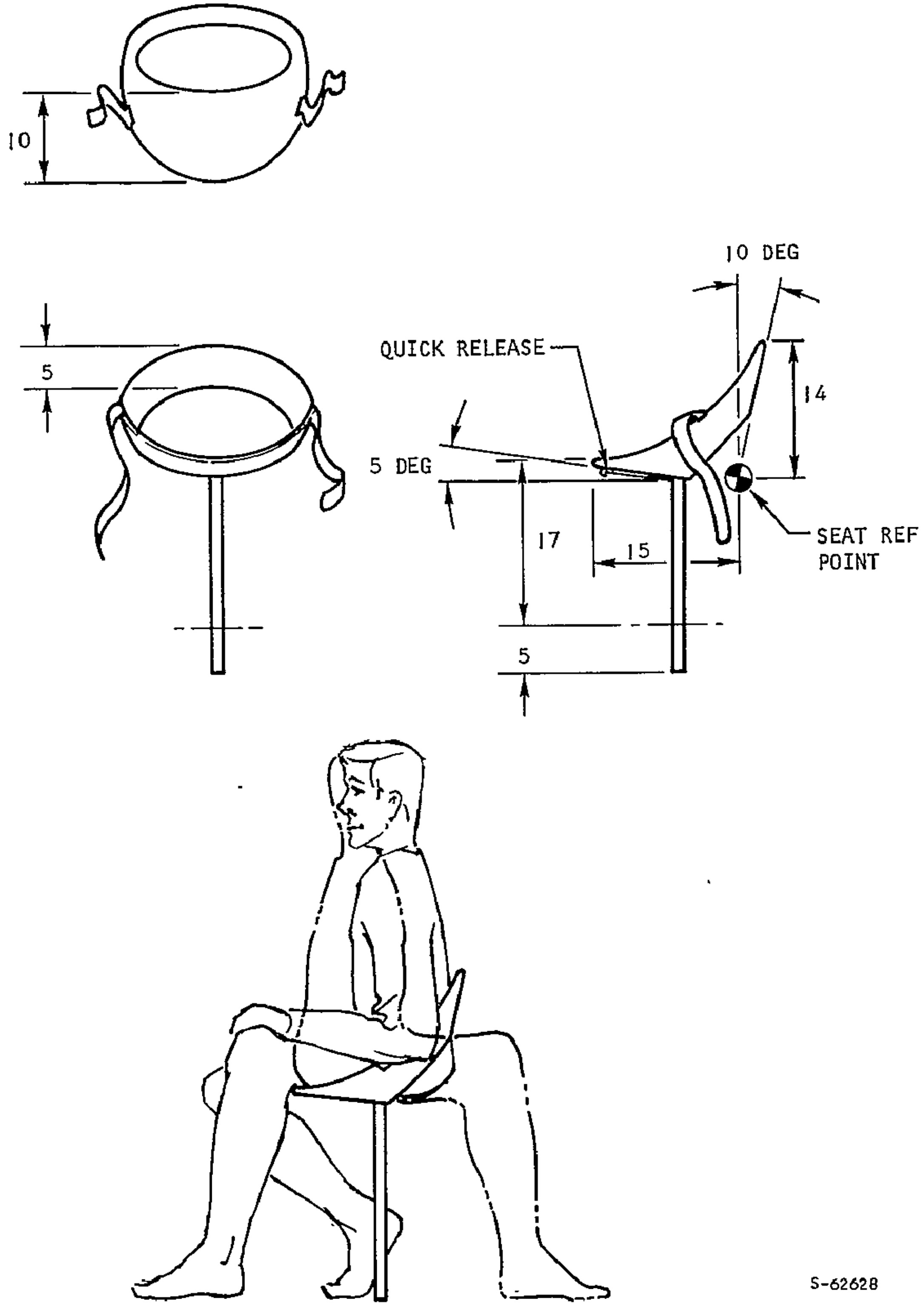

Figure 9-19. Ribbon Restraint

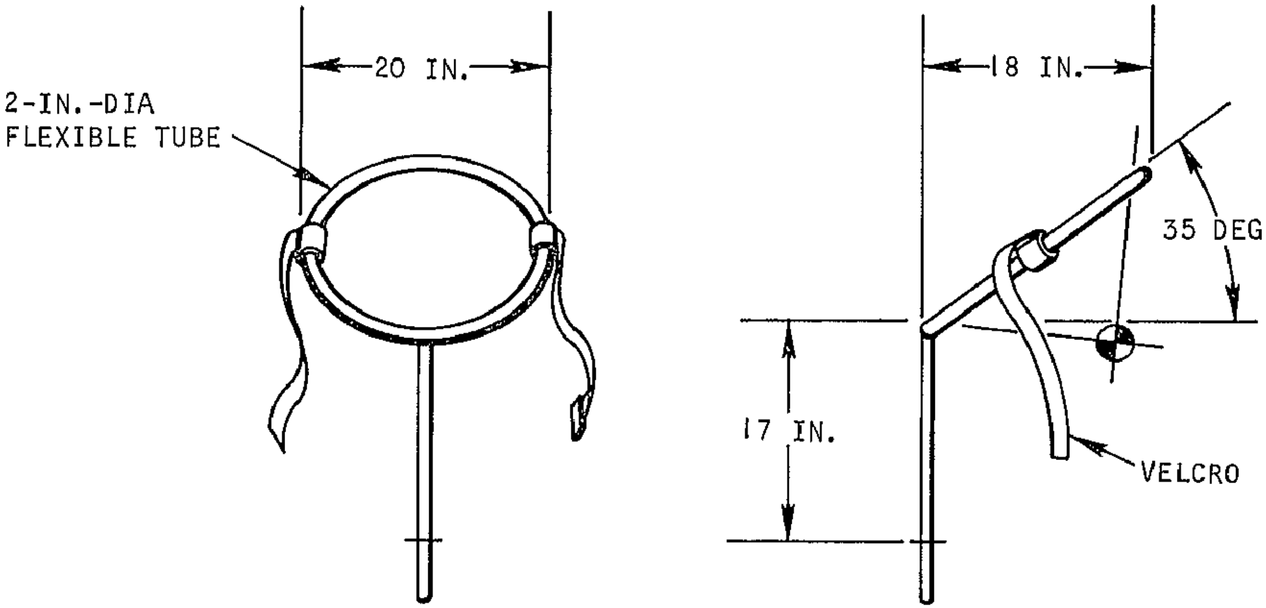

Figure 9-20. Tubular Seating Restraint

Note: The tubular seating restraint can be used as depicted by the man shown in fig. 9-19.

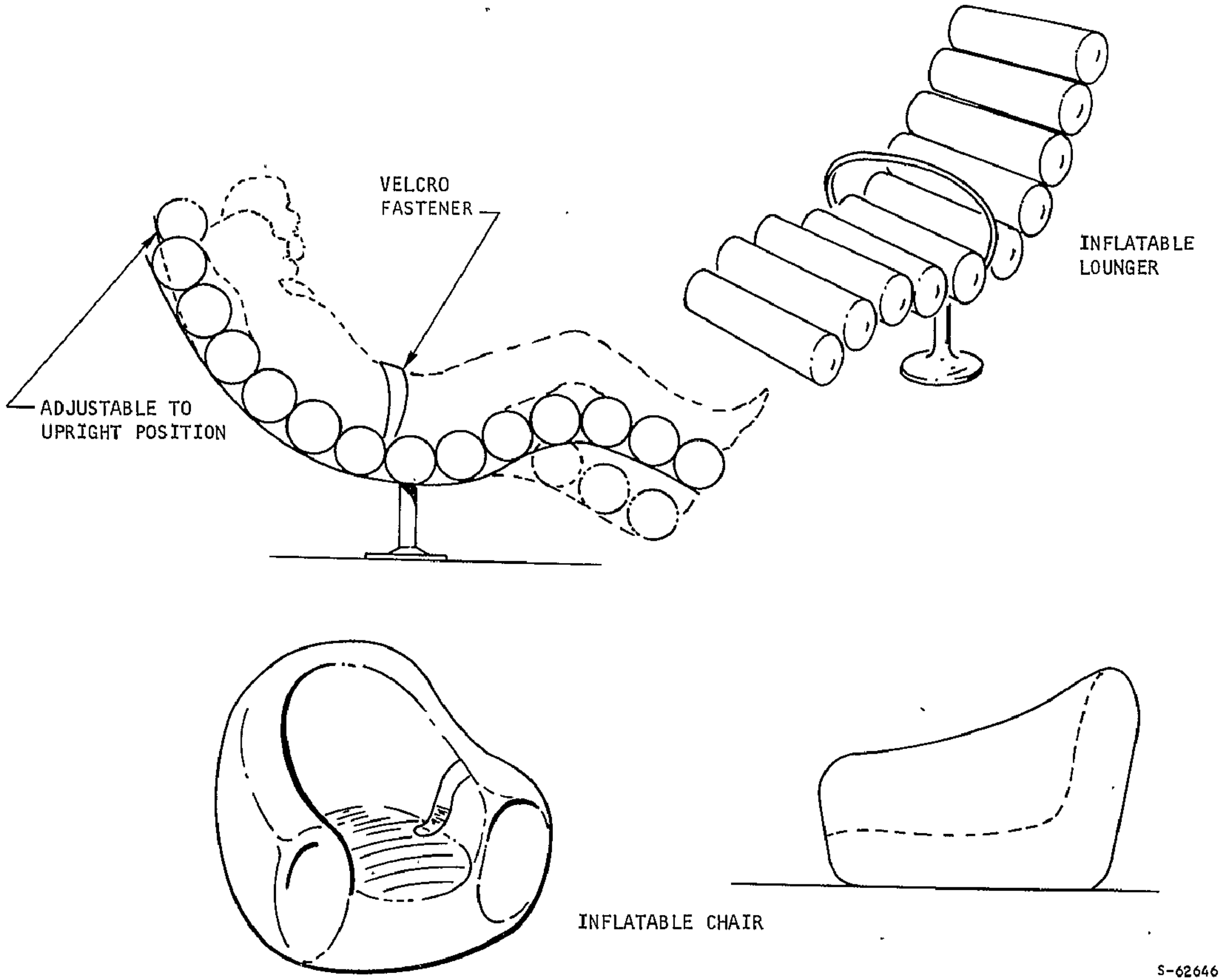

Figure 9-21. Inflatable Lounge Chairs for Wardroom

Figure 9-22. Rectangular Wardroom Mockup

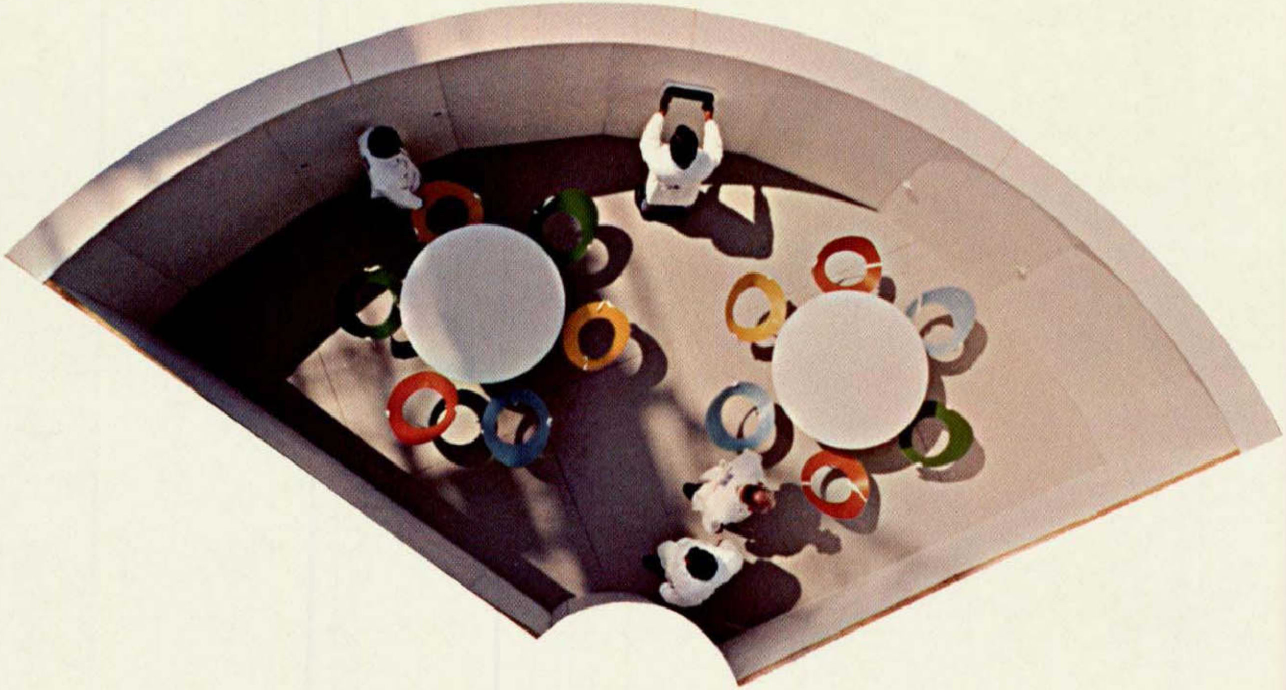

Figure 9-23. View Showing Passing Space Between Chairs and Walls

man is passing between a chair and the wall, while another crewman is using a wall-mounted oven. By placing the oven between the tables, the round shapes make use of the open space most efficiently. In fig. 9-24, two men are shown passing the main aisle from the entrance to the oven. Fig. 9-25 shows the entire crew of twelve men seated at the round tables in the wardroom. There is ample volume for maneuverability. This volume increase also provides a much more pleasant "feel" than does the minimum volume. The food storage, preparation, and restraint device is shown in fig. 9-26. A straddle-type restraint is used to hold the crew member in position, and the food package is inserted between two tubes that hold the package in place by the friction of their deflection. A microwave oven that is mounted in the center rotates for accessability to all. Food for short-term use (7 days) is stored in the leg of the hexagon for each crewman. In fig. 9-27, an alternate oven is shown; it is in a cylindrical form so that the dichromatic finish shown in fig. 5-1 can be used effectively. The entire food unit requires about the same volume as the round table, as shown in fig. 9-28.

This wardroom volume used as an exercise area is shown in fig. 9-29. Four men are shown using the various exercise devices. One is riding the ergometer while the others are employing spring and bungee cord stretch devices. Tables are stowed on the wall, and the chairs are stacked in the corners. It is clear from this picture that more than four men can exercise at one time if the area is cleared. Fig. 9-30 shows ten men in the wardroom watching a movie. This number is expected to be the average because one man will be on duty and the other one may wish to perform personal tasks. This arrangement shows that all members have a good viewing of the beaded screen. In fig. 9-31 the crew members are shown looking toward the screen; also shown are the seating restraints and the aisle space. Modular placing of receptacles will permit the chairs to be placed where the individual can best see.

Arrangement of space for a wardroom in a cylindrical form, as shown in figs. 9-32 and 9-33, seems to be well suited for the required functions. Changeover for the different uses must be made easily and simply without using any of the clear volume shown. The next step is to verify this volume in a zero-g environment.

VI

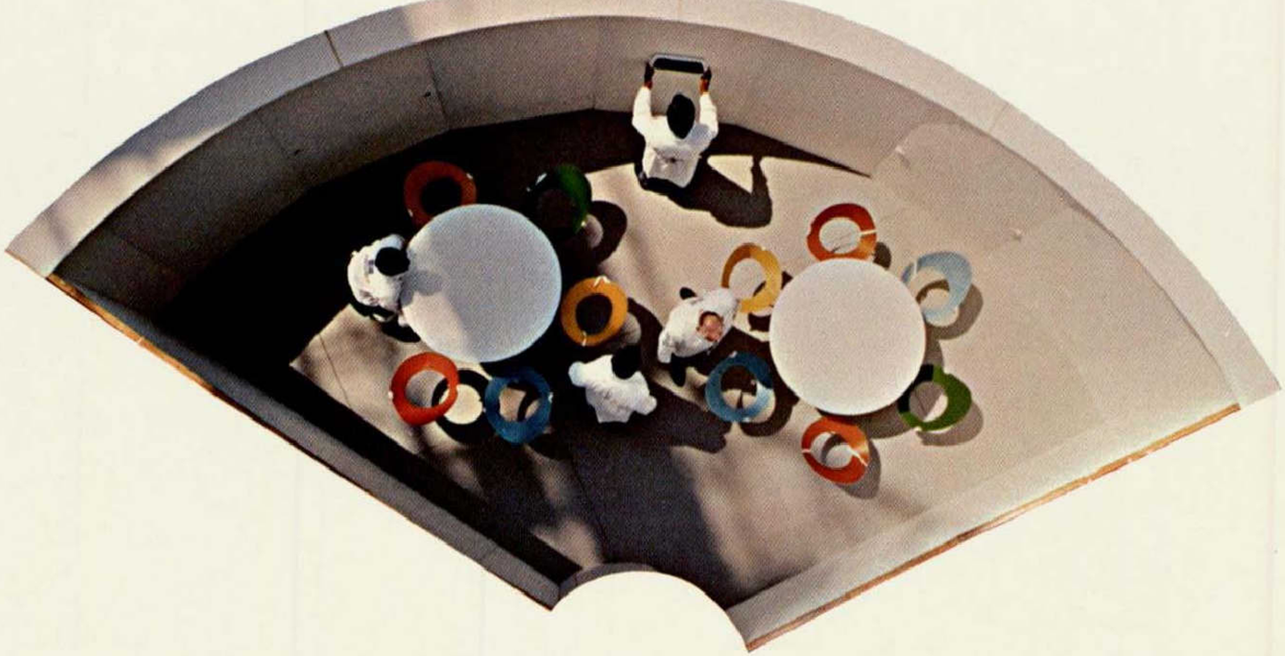

Figure 9-24. View Showing Two Men Passing Between Tables

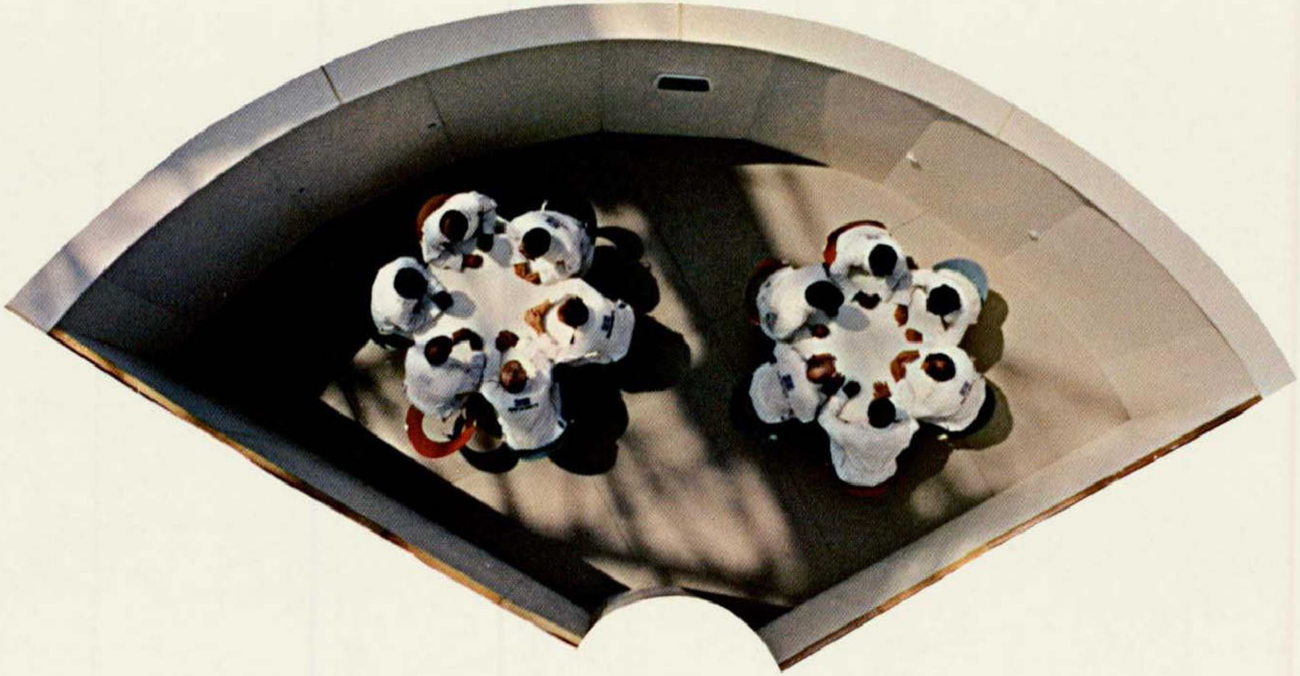

Figure 9-25. Entire Crew (12 Men) Dining

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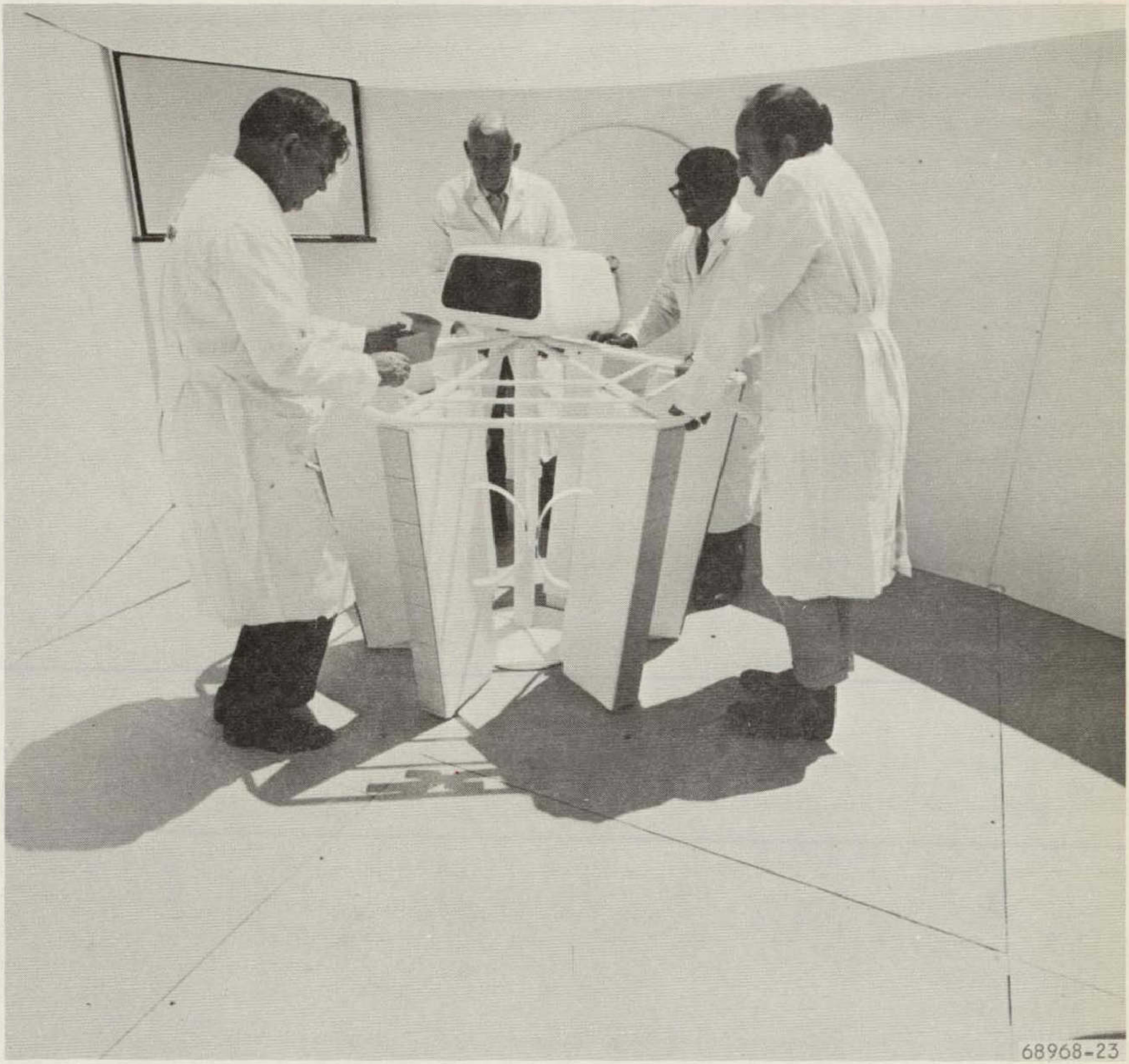

Figure 9-26. Food Storage, Preparation, and Restraint Device

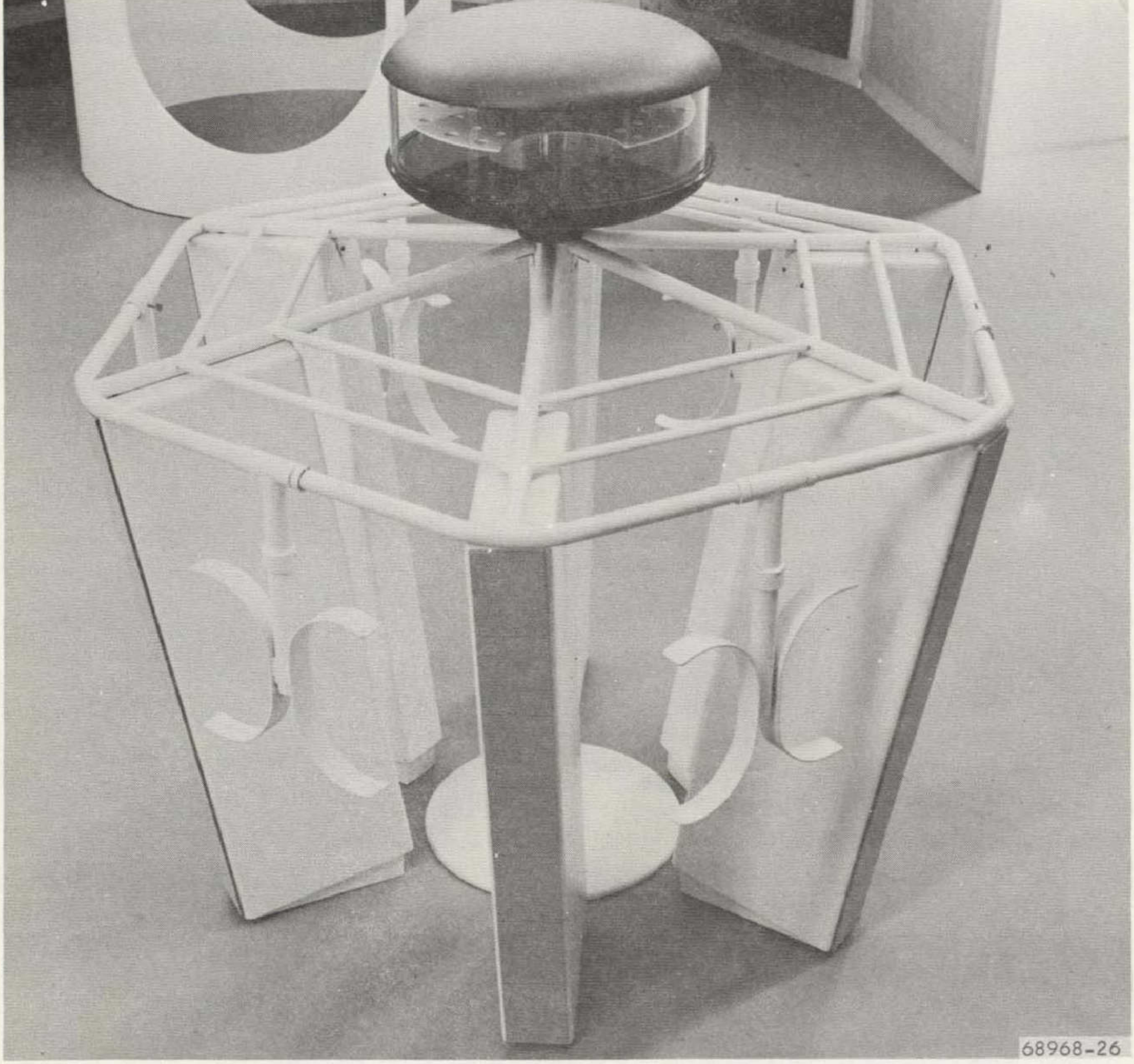

Figure 9-27. Alternate Food Preparation Device

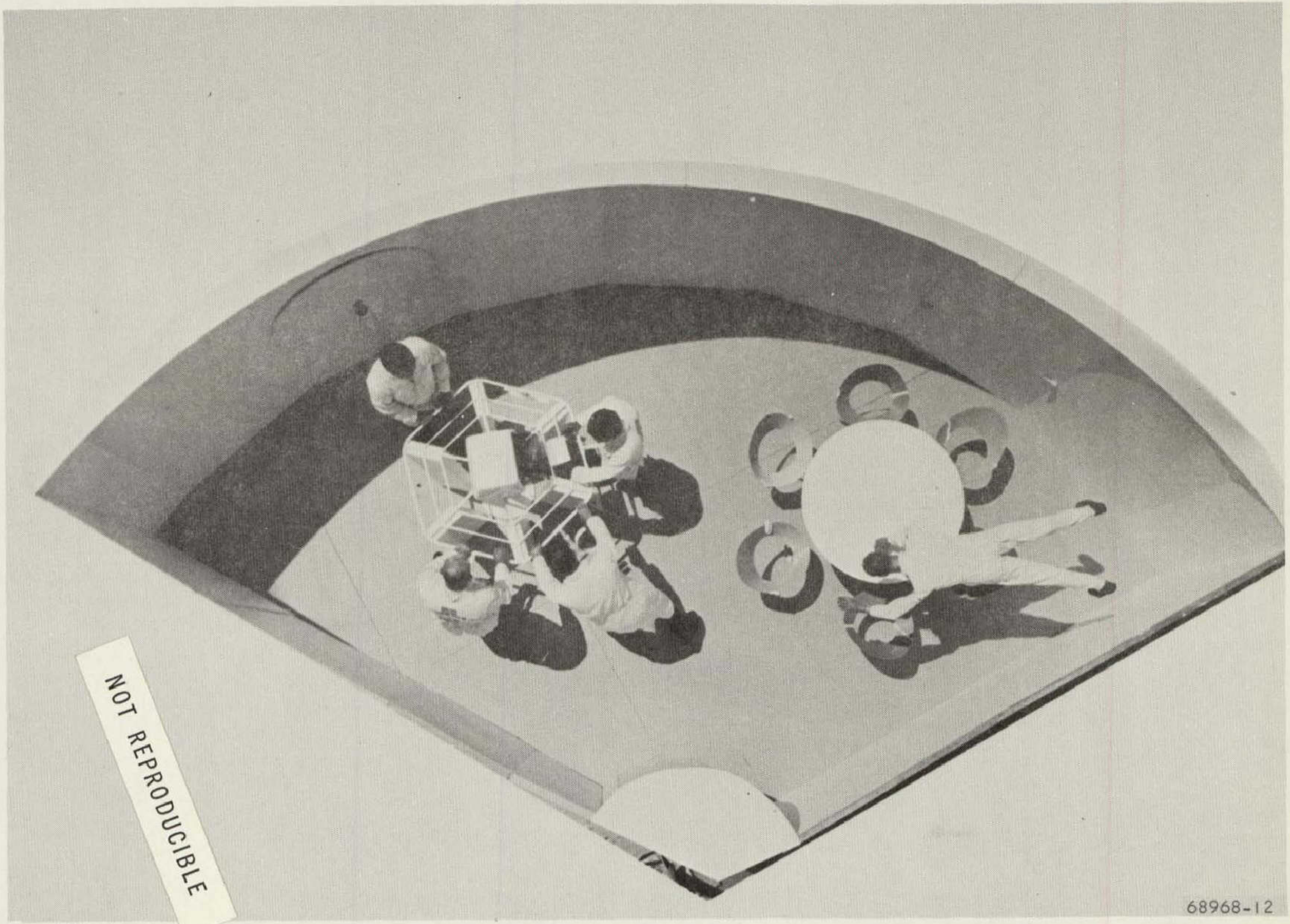

Figure 9-28. Food Unit Volume Requirement
(Same as Round Table)

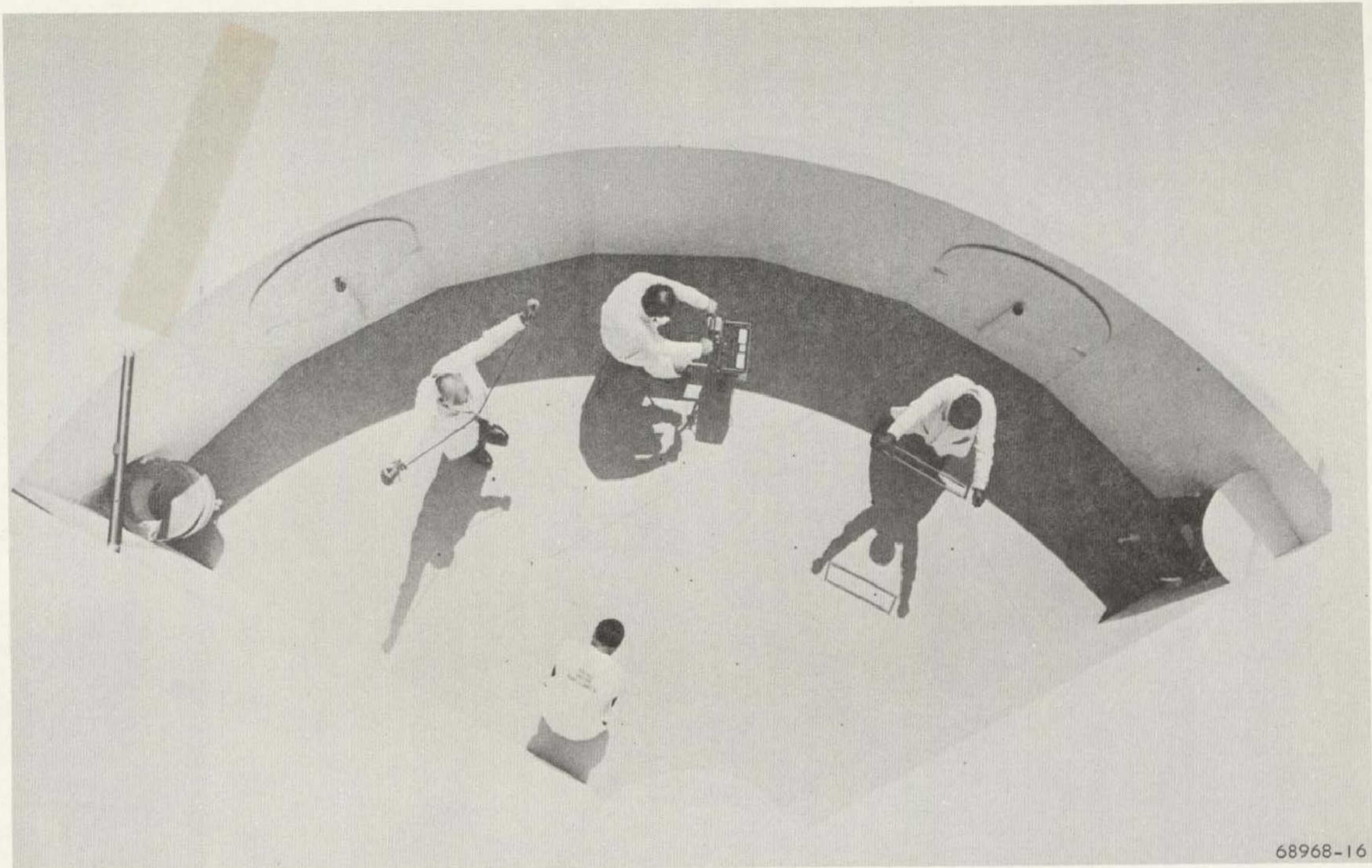

Figure 9-29. Crew Members Exercising in Wardroom Volume

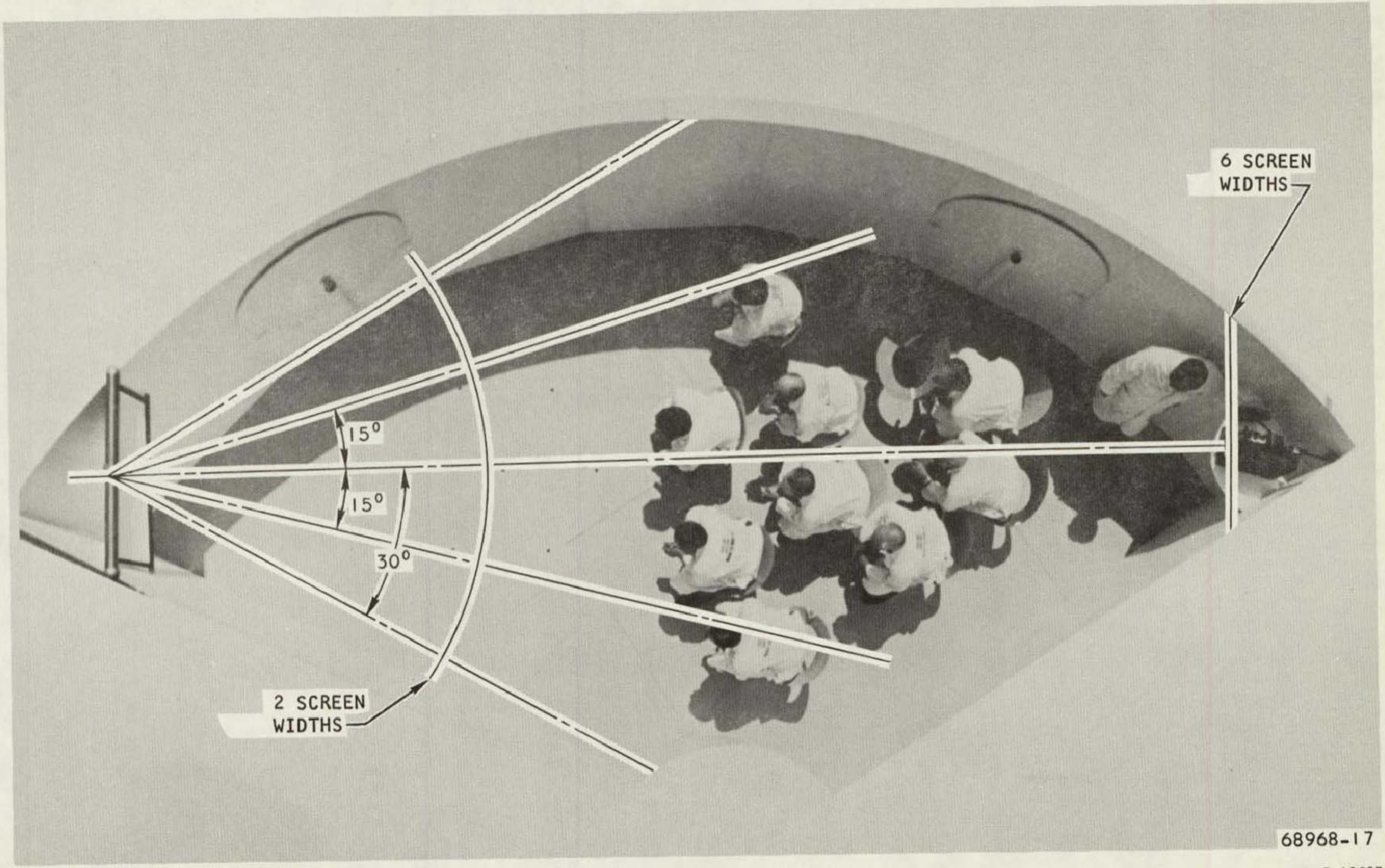

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Figure 9-30. Comfort Viewing Using a Beaded Screen

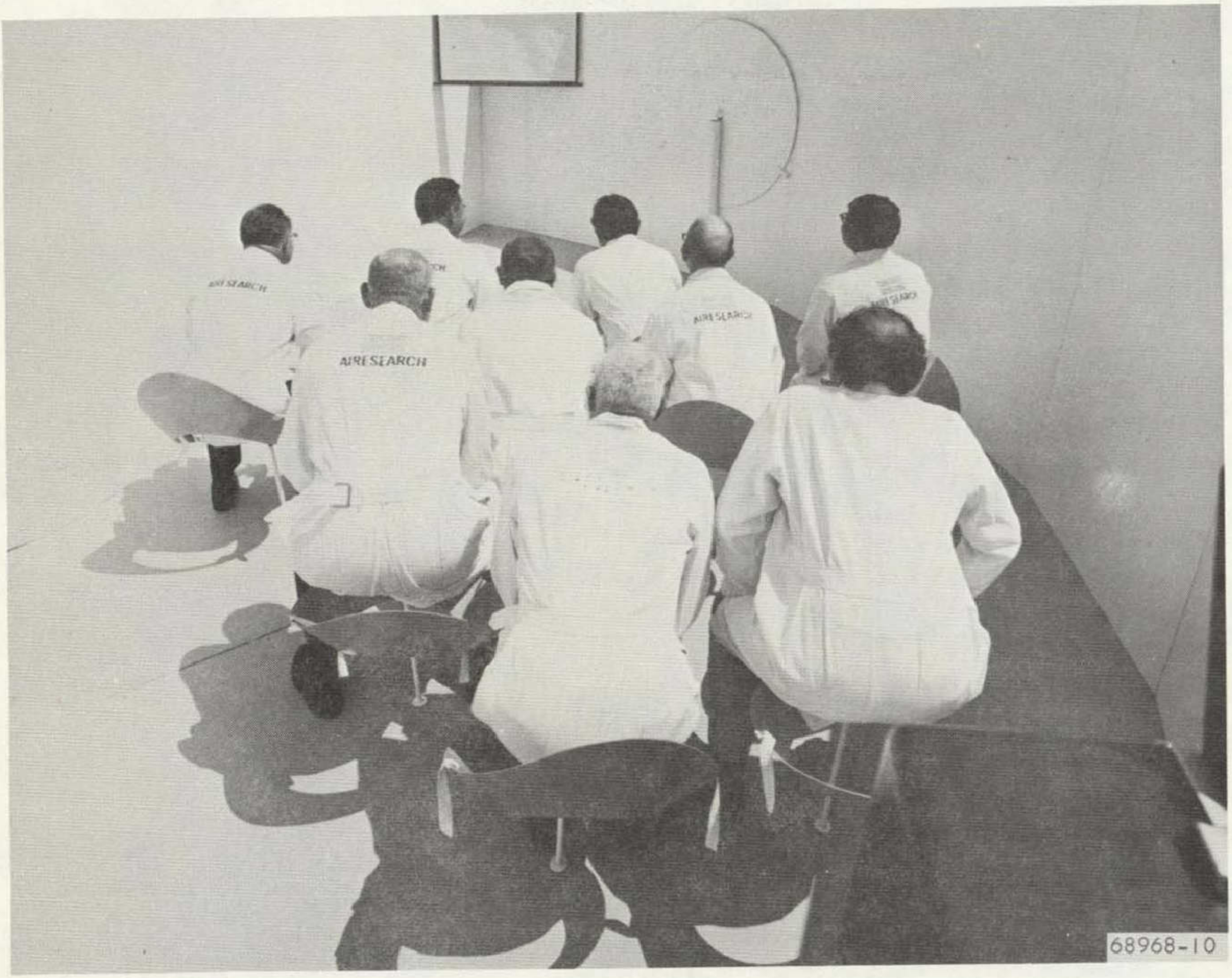

Figure 9-31. Crew Members Viewing Screen

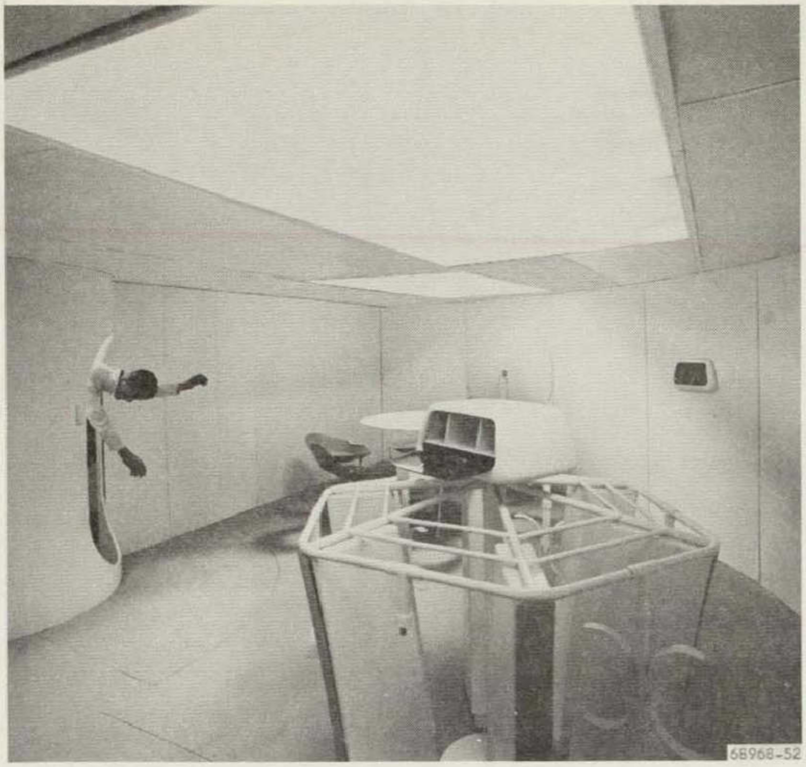

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Figure 9-32. Table and Eating Restraint Arrangement in Wardroom

Figure 9-33. Use of Color in Wardroom

CONCEPTUAL CRITERIA AND STANDARDS

Wardroom conceptual criteria and standards are listed in table 9-7. These are subdivided under the functions for eating, exercise, operational, recreation, and medical.

FUNCTIONS ANALYSIS (WARDROOM)

As was the case for the privacy area, the functions of the wardroom are analyzed primarily to structure compartment requirements into preliminary actions that would be accomplished by space station personnel and equipment. The wardroom must serve as a multi-use area that provides for sustenance, recreation, exercise, and assembly. These first-level functions are discussed in Section 2, and they can be subdivided into the second-level functions described below. Since only the privacy area, wardroom, and hygiene area are discussed in this report, the functions analysis is not final. This preliminary analysis can be finalized only when it is incorporated into a total mission functions analysis.

Provide Sustenance

The provide sustenance function can be subdivided into the second-level functions shown in fig. 9-34. Further subdivision of the second-level functions yields the tasks that are detailed in the task analysis discussion at the end of this section.

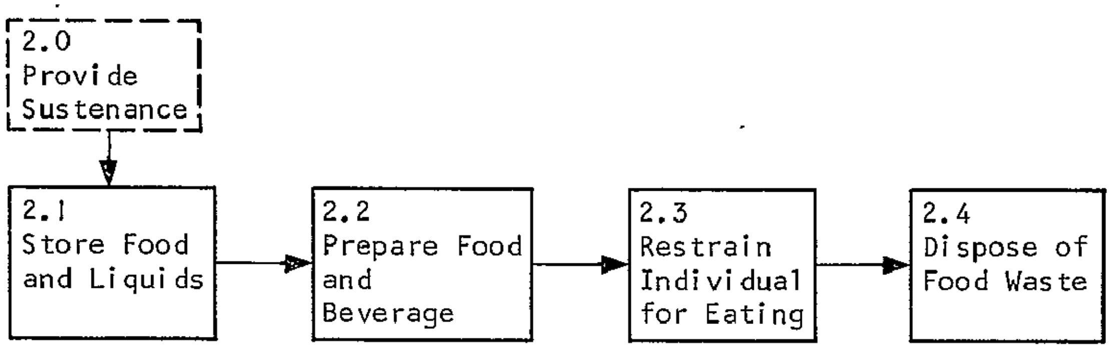


Figure 9-34. Second-Level Functions for Sustenance

Block 2.1--Store Food and Liquids

Food and potable water must be stored as well as emergency rations for twelve men for the complete mission. The tremendous volume and weight for this requirement may necessitate resupply on a planned schedule.

TABLE 9-7

WARDROOM CONCEPTUAL CRITERIA AND STANDARDS

Criteria	Standards
Eating	
1. Provide space for the entire crew to eat together at one time.	1. 15 ft 6 in. by 9 ft (minimum); 20 ft by 12 ft (preferred)
2. Provide restraints for the crew and the food.	2. Seated restraints for crew and quick-release or friction restraint for food.
3. Entrance must be large enough for 2 men to pass.	3. 42 in. wide by 58 in. high (preferred); 30 in. wide by 58 in. high (minimum).
4. Emergency exit must be provided in the event that the main entrance is blocked.	4. Emergency exit minimum of 30 in.-dia, 36 in.-dia preferred.
5. Interior should be soft with provision for mobility.	5. Pad all hard surfaces, no sharp corners. Hand holds on ceiling and food traction on floor.
6. Provide a means of telling time. Minutes, hour, day, month, and year.	6. Clock in prominent location for all to view along with calendar.
7. Provide food storage.	7. Store as much in the wardroom as good design will permit. Remainder will be stored elsewhere for easy replenishment as food is consumed.
8. Provide for rapid food preparation.	8. Microwave oven or hot water injector.
9. Provide for waste disposal that is odor free.	9. Sealed containers that will contain the sealed pockets forming double odor seal.
10. Supply cleaning materials and storage space.	10. Cleaning materials that are compatible with the finishes and are nontoxic must be included.
Exercise	
1. Physiologic conditioning	1. Ground level training and baseline data. Inflight use of 2 bicycle ergometers for 2 or 3 15-min exercise periods per day at heart rates of 140 to 160 beats per minute.
2. Muscle toning	2. Massage, isometric exercises, etc., (see text).
3. Provide space for at least 4 men and preferably 6 men to exercise at one time.	3. 15 ft 6 in. by 9 ft (minimum); 20 ft by 12 ft (preferred)
4. Provide storage for exercise equipment.	4. 3 ft by 3 ft by 2 ft
5. Design for a minimum of change to equipment or facility.	5. Hinge ergometers to stowage compartment and attach other exercise devices to structure.
6. Provide restraints necessary for exercising at zero-g.	6. Foot and hand restraints as required by the exercise devices selected.
Operational	
1. Provide space for the entire crew to assemble.	1. 15 ft 6 in. by 9 ft (minimum); 20 ft by 12 ft (preferred)
2. Provide space for the crew to assemble and the relief crew (24 men).	2. Same as above
3. Provide escape hatch.	3. 30-in. dia
4. Provide audiovisual equipment	4. 15-mm movie and 35-mm still projector, and an overhead-type projector.
5. Provide light control.	5. Light dimming control
6. Seating restraints that are easily moved.	6. Seating restraints to be designed with quick-release fasteners and capable of being stacked for conserving volume.
7. Spilled liquid retriever for collecting floating globules of liquids.	7. Portable suction device with a tank for collecting, storing, and transporting liquid to a receptacle.
8. Provide supplies for maintaining interior cleanliness.	8. Wipes impregnated with a cleaning liquid that is compatible with the finishes; also rags for drying.
Recreation	
1. Provide seating space for 12 men for audiovisual viewing.	1. Design for normal projection viewing in 15-ft 6-in. by 9-ft area (minimum space); 20-ft by 12-ft area preferred.
2. Provide zero-g restraints.	2. Quick-release belts with velcro.
3. Provide for audio entertainment.	3. Speakers for community listening and head sets for private listening.
4. Provide seating and table for head-to-head games (2 or more participants).	4. Dining tables and seating restraints can be used for games.
5. Provide for individual lounging for reading, listening to music, or resting.	5. Lounge-type seating restraint.
Medical	
1. Medical personnel	1. Medical doctor or corpsman trained crewman and backup.
2. Emergency care	2. Extensive first aid training for all crewman.
3. Medical equipment and supplies	3. Medical chest as described in text.
4. Medical library	4. Microfilm reader or equivalent display.
5. No sharp projections or free floating objects.	5. Rounded and/or padded corners and restraint storage of all materials.
6. Medical examination area	6. Privacy screen (removable) and medical supply storage in the wardroom. Dispensary area doubling for sleeping area for medic. Requires environmental isolation, medical supply storage, and surface with straps for examinations.
7. Maintain fitness	7. 2 lower body negative pressure units, 2 bicycle ergometers, or 2 MOL exercisers should be installed in the wardroom.

Block 2.2--Prepare Food and Beverage

Food can be presented to the crew, or the crew to the food, for pickup and preparation. Food will be heated by a rapid means commensurate with the type selected. Rapid heaters such as microwave ovens were considered in this study as a typical volume. A temperature-controlled liquid injector is provided for the hot or cold beverages.

Block 2.3--Restrain Individual for Eating

Restraints must be provided for the entire crew and their food. The normal sitting position for eating is assumed with the food restrained on the table or device in front of the individual. No restraint will be required for liquids because beverages will be consumed from a liquid injector. Crew members will be provided with individual mouthpieces for drinking.

Block 2.4--Dispose of Food Waste

Uneaten food, both dry and liquid, must be disposed of in sealed containers to provide odor control. Also, containment of probable bacterial and fungus growth must be provided to avoid undue spread or aerosolization on contact.

Facilitate Recreation

The function to facilitate recreation can be subdivided into second-level functions to provide for group active games, provide for group passive games, and provide projection capability. These functions are shown in fig. 9-35.

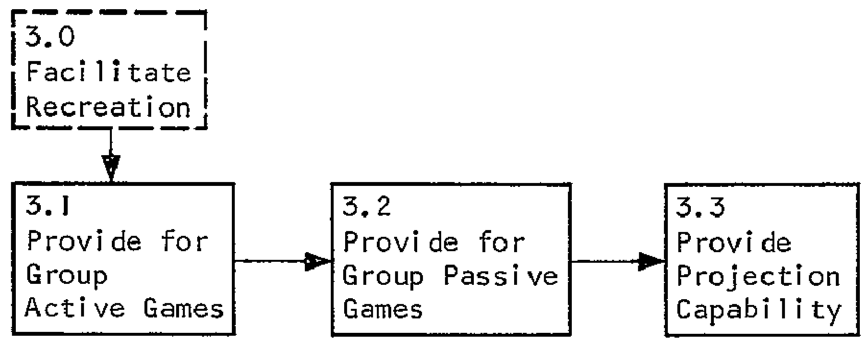


Figure 9-35. Second-Level Functions for Facilitating Recreation

Block 3.1--Provide for Group Active Games

Group active games during long-duration space flight should be provided so that individual members can (1) minimize physiologic deconditioning, and (2) pursue athletic interests. Modifications of earth-bound sports such as

handball, baseball, and volleyball could provide very interesting and challenging games. Thus, basic athletic skills developed while living on earth could be transferred to the zero-g condition for maintaining coordination. Hand/eye coordination is especially important for the accurate performance of critically fine tasks.

Block 3.2--Provide for Group Passive Games

Group passive activities are necessary for reducing tension and allowing relaxation. Examples of passive activities are group viewing of television (football games, etc.), card games (bridge, pinochle, etc.), chess, scrabble, etc. It is most likely that special games will need to be developed specifically for best fulfilling astronaut needs during long-duration zero-g spaceflight. Tektite observation of leisure time activities indicated the need for a wide selection of recreational and socially stimulating items. Variety is the most frequent complaint, in spite of rather extensive onboard leisure facilities. There also was considerable demand for news reports, suggesting another use for the audiovisual viewer.

Block 3.3--Provide Projection Capability

Projection capability is necessary to provide motion picture entertainment, slides, or images of specially developed games. The restraint problems that will be encountered for most passive games now played could be eliminated by using projected images of game configurations. Configuration changes could be effected by instructions input to a computer. The flexibility of such a device would allow reprogramming of software so that a multitude of passive games (Gomoku, chess, etc.) could be available during long-duration spaceflight with a minimum weight penalty.

Maintain Physical Condition

The maintain physical condition function can be subdivided into the second-level functions shown in fig. 9-36. These functions are to provide for calisthenics, individual exercise, and group motor sports.

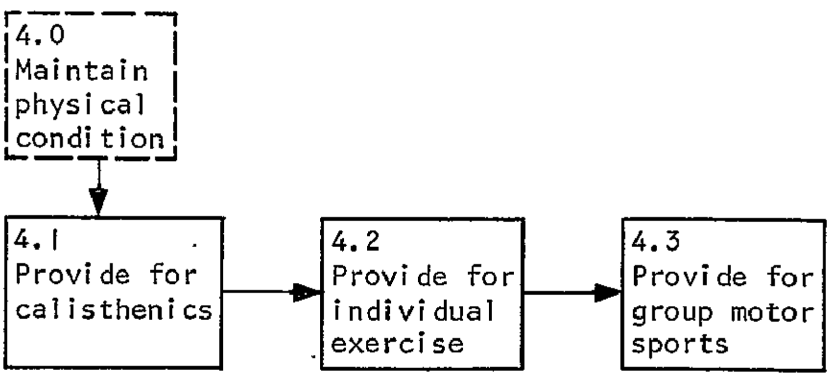


Figure 9-36. Second-Level Functions for Maintain Physical Condition

Block 4.1--Provide for Calisthenics

Space for scheduled exercise activities in which an ergometer, bungee, or other exercise device is used must be allotted. The space required will change with the number of crew scheduled for calisthenics at any one time. One, two, three, or more members can be scheduled for a planned program of calisthenics.

Block 4.2--Provide for Individual Exercise

Plans should include equipment and facilities for individual exercises as scheduled (spring hand-grip, dynamometer). All of these exercises should be performed in the wardroom; however, some may be done in the sleep area or duty station, depending upon the exercise in question. Experience has shown that exercises must be scheduled and performed in a group to be effective.

Block 4.3--Provide for Group Motor Sports

Space should be allocated for competitive sports where participants can be restrained while participating. Examples of these include wrestling, arm wrestling, etc. Group motor sports are closely related to active games. If the participating astronauts are engaged in an active game for the purpose of exercise, and not for enjoyment, the activity is classified as a group motor sport. Sports are those activities engaged in for the sheer pleasure of competition and activity.

Provide Medical Care

The function to provide medical care can be subdivided into the second-level functions shown in fig. 9-37. These are to provide medical space, provide medical equipment, and provide medical personnel.

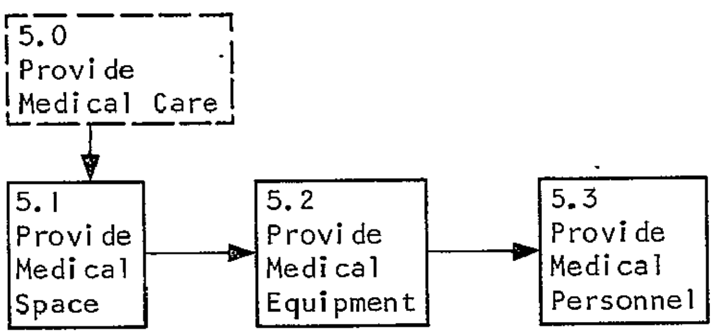


Figure 9-37. Second-Level Functions to Provide Medical Care

Block 5.1--Provide Medical Space

A privacy area must be set aside in the design for performance of medical evaluations. The dispensary area should include a surface with straps that could be used as an examining table. This dispensary space should be fitted with

special filters, etc. in the ECS system so that it could be used as an isolation room. One of the unknown aspects of long-duration space flight is the effect of abnormal atmospheres on man's normal bacterial flora. Man normally carries pathogenic types of bacteria, e.g., Staphlococcus aureus, Streptococcus sp., etc., in a nonvirulent form. Exposure to abnormal atmospheres may cause bacterial mutations to virulent forms and/or reduce the physiologic resistance of the crew members to their normal flora so that pathological conditions could occur.

Block 5.2--Provide Medical Equipment

A medical chest with drugs and supplies must be available for symptomatic treatment or specific therapy of diseases that might be encountered. Such diseases have been identified by the Space Medical Advisory Group (SPAMAG) as:

(1) Respiratory illness

(2) Urinary infections and stones

(3) Gastrointestinal disturbances such as mucous colitis, gastitis, Peptic ulcer, or diarrhea of infectious or other origin

(4) Cardiac arrhythmias

(5) Disturbed emotional state

(6) Aspiration of foreign body

(7) Minor trauma

(8) Burns

(9) Foreign body in the eye

Block 5.3--Provide Medical Personnel

A physician is highly desirable as a crew member, both to provide medical surveillance and treatment and to perform physiologic and medical experiments. A foremost consideration is whether a medical doctor can be fully utilized as a crew member. The feasibility of having a medical doctor as a crew member is related to the division of skills of the entire crew in terms of the totality of tasks required. A physician expert in environmental physiology could be useful in operation and maintenance of life-support systems and could be trained in tasks related to laboratory missions. On the other hand, the diversity of other tasks required of the crew might dictate that crew members with other skills be preferred, in which case one or more of them would be given adequate medical training and experience in handling emergencies.

Assemble Crew

The assemble crew function can be subdivided into the second-level functions shown in fig. 9-38. These are provide assembly restraints, present audiovisual information, and vary illumination.

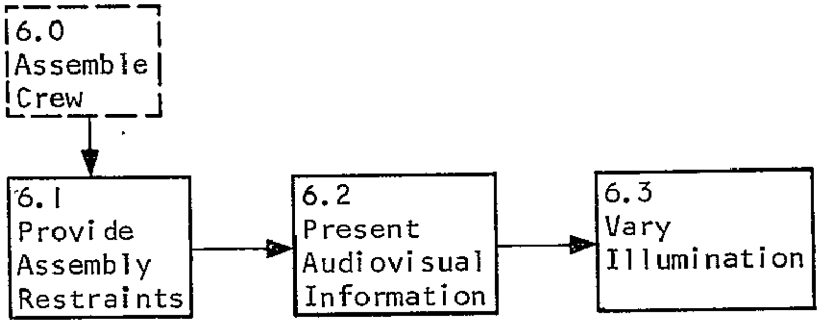


Figure 9-38. Second-Level Functions for Assemble Crew

Block 6.1--Provide Assembly Restraint

Crew members that assemble in the wardroom should have restraints available. Crew members should be restrained by some type of force-cancelling device in the normal seated position and provided with a table that can be used for writing notes.

Block 6.2--Present Audiovisual Information

Audiovisual information can be presented to both crews for briefings, information, education, and recreation. Normally, only one crew will be present; during the rotation period, the replacement crew will require briefing before taking over. Projection devices and screens will be required.

Block 6.3--Vary Illumination

Illumination control is required to support the presentation of information. If projection techniques are used, ambient illumination should be dimmed. Graphical training aids will require higher illumination levels. Controls should be located in one control device to provide the speaker with complete control of the presentation during an assembly.

TASK ANALYSIS

To further delineate wardroom requirements for space station personnel, tasks to be performed by these personnel in the wardroom are described in the following preliminary task analysis forms (fig. 9-39). Tasks and equipment can be finalized only after a total mission has been defined and studied. Task analysis forms have been completed for each wardroom function discussed in this section. The information loop is shown beginning with the task description information, proceeding through decision, and ending with feedback. Performance deviations are the result of events that do not proceed normally, or what will happen if the expected event does not occur. Additional equipment are those items that must be used to assist in bringing about the stated event such as hand tools. Location in the craft, frequency of occurrence, and elapsed time are all entered on this form. The data is useful for supportive analyses such as time line charts and link analysis. General items are carried in the remarks column along with an estimated volume of the hardware being considered.

2. PROVIDE SUSTENANCE

TASK ANALYSIS OF: STORE FOOD AND LIQUIDS

SECOND-LEVEL FUNCTION NO: 2.1

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Open food storage compartment door	Wardroom	3 times each 24 hr for each crewman	5 sec		Schedule	Activate latch and swing open door	Visual and tactile Door opens	Door malfunction Will affect performance or mission duration	Foor storage compartment	Food and beverage storage refers to consumables used for meals and snacks
	Select food	Wardroom	3 times each 24 hr for each crewman	30 sec		Food display	Meal selection	Visual Quantity/type of food available	Inadequate quantity/quality Will affect mission success		The volume required for food storage for a total mission is too large for the wardroom.
	Remove food from storage	Wardroom	3 times each 24 hr for each crewman	10 sec		Selected food	Grasp food package and remove	Tactile	Damage food packet Precludes normal preparation--possible schedule disruption		Tradeoff must be made where the best amount will be stored. The remainder will be provided by resupply craft.
	Close food compartment door	Wardroom	3 times each 24 hr for each crewman	5 sec		Procedure	Swing door to closed position	Visual, tactile, auditory Door closes; latch activates	Door malfunction Food spoilage will affect mission schedule and become health hazard		
	Open beverage storage compartment door	Wardroom	3 times each 24 hr for each crewman	5 sec		Perference or thirst level	Activate latch and swing door open	Visual and tactile Door opens	Door malfunction Will affect performance or mission duration	Beverage storage compartment	
	Select beverage	Wardroom	3 times each 24 hr for each crewman	10 sec		Beverage display	Select beverage	Visual Quantity and type available	Inadequate quantity and quality Will affect mission success		
	Remove beverage from storage	Wardroom	3 times each 24 hr for each crewman	10 sec		Selected beverage	Grasp beverage container and remove	Tactile	Damage beverage container Possible loss of beverage will disrupt schedule		

Figure 9-39. Task Analysis

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Close beverage storage compartment door	Wardroom	3 times each 24 hr for each crewman	5 sec		Procedure	Swing door to closed position	Visual, tactile, and auditory	Door malfunction		
								Door closes, latch activates	Possible beverage spoilage will become hazardous and affect the schedule		

Figure 9-39. (Continued)

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Open food package	Wardroom	3 times each 24 hr for each crewman	15 sec		Selected food	Pull opening tab	Visual and tactile Tear away cover on package	Pull tab malfunction Possible delay of daily schedule		This task may be omitted for some food types
	Open infrared (IR) oven	Wardroom	3 times each 24 hr for each crewman	5 sec		Procedure	Activate latch and swing door open	Visual and tactile Quick opening positive latch	Latch malfunction Possible delay of daily schedule		
	Place food packet in IR oven	Wardroom	3 times each 24 hr for each crewman	5 sec		Food packet open and oven door open	Grasp food packet and place in oven	Visual and tactile			
	Close IR oven	Wardroom	3 times each 24 hr for each crewman	5 sec		Procedure	Swing door to closed position to activate latch	Visual, tactile, auditory Positive closing latch	Latch malfunction Possible delay of daily schedule		
	Activate oven	Wardroom	3 times each 24 hr for each crewman	3 sec		Procedure	Activate switch to on position; set timer	Visual Indicator light	Switch malfunction Schedule delay		
	Prepare food	Wardroom	3 times each 24 hr for each crewman	--		Automatic		Visual, Auditory Ready light and buzzer	Oven or timer malfunction Spoiled food, could affect mission stay time		
	Remove food packet from IR oven	Wardroom	3 times each 24 hr for each crewman	5 sec		Food ready for eating	Grasp food packet and remove	Visual, tactile			
	Open beverage package	Wardroom	3 times each 24 hr for each crewman	5 sec		Selected beverage	Remove seal from package opening	Visual, tactile Twist-pull type seal	Seal malfunction Possible schedule delay and loss of beverage		

Figure 9-39. (Continued)

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Connect beverage package to H_2O injector	Wardroom		15 sec		Procedure	Push and twist connector	Visual, tactile	Connector malfunction		Care must be exercised to prevent inadvertent spillage of liquids
								Positive lock mating sequence with automatic pressure equilization	Schedule delay, loss of beverage, possible ship contamination		
	Select hot or cold H_2O as applicable	Wardroom		5 sec		Selected beverage	Set selector switch	Visual, tactile	Switch malfunction		
								Indicator light, automatic volume control	Schedule delay		
	Activate H_2O	Wardroom		5 sec		Procedure	Activate switch	Visual	Switch malfunction		
								Indicator light	Schedule delay		
	Prepare beverage	Wardroom		--		Automatic		Visual, auditory	Unit malfunction		
								Ready light and buzzer	Spoiled beverage, possible affect on mission duration		
	Remove beverage	Wardroom		10 sec		Beverage ready for drinking	Grasp beverage package: push and twist for release	Visual, tactile	Connector malfunction		
									Schedule delay, loss of beverage, possible ship contamination		
	Connect mouthpiece	Wardroom		10 sec		Procedure	Push and twist connector	Visual, tactile	Same as above		

Figure 9-39. (Continued)

2. PROVIDE SUSTENANCE

TASK ANALYSIS OF. RESTRAIN INDIVIDUAL FOR EATING

SECOND-LEVEL FUNCTION NO: 2.3

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Restrain food package	Wardroom		30 sec		Food prepared	Position food package in holder at eating station	Visual, tactile	Food moves out of reach		
								Food package fits in restraint unit	Eating will be difficult; possible food spill		
	Restrain beverage	Wardroom		30 sec		Beverage prepared	Position beverage container in holder at eating station	Visual, tactile	Beverage container moves out of reach		
								Beverage container fits in restraint unit	Possible spill		
	Restrain body	Wardroom		30 sec		Food and beverage restrained	Position body and fasten restraint	Visual, tactile	More cannot be eaten		
								Body secured to eating station	Unduely long delay in eating		
	Ingest food and beverage	Wardroom		--							

Figure 9-39. (Continued)

2. PROVIDE SUSTENANCE

TASK ANALYSIS OF: DISPOSE OF FOOD WASTE

SECOND-LEVEL FUNCTION NO: 2.4

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Remove used food packet from restraint	Wardroom		15 sec		Completed meal	Grasp packet and remove from holder	Visual, tactile Packet snaps free of holder	Packet does not snap free of holder		
	Seal food packet	Wardroom		30 sec		Used food packet released from holder	Seal packet in special container or reseal original packet	Visual, tactile Packet is completely sealed	Complete seal not achieved Possible odor and bacteria growth		Inspect packet for leaks. Reseal if any leaks are in evidence.
	Deposit waste packet in system container	Wardroom		30 sec		Sealed food packet	Open container hatch, deposit waste	Visual, tactile Hatch closes automatically	Hatch malfunction Possible odor, bacteria growth; possible health hazard		

Figure 9-39. (Continued)

3. FACILITATE RECREATION

TASK ANALYSIS OF: PROVIDE FOR GROUP ACTIVE GAMES

SECOND-LEVEL FUNCTION NO: 3.1

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Open game storage compartment	Wardroom		15 sec		Preference	Activate latch and open door	Visual, tactile Positive operating latch and door. Storage area is open	Door malfunction Will delay game	17-in.-dia by 3/4-in.-thick board; 5-in. by 3-in. by 1-1/2-in. darts	
	Select game board and darts	Wardroom		30 sec		Open storage area	Make selection	Visual Identify and locate game	Nonavailability, needs repair Affects recreation schedule		
	Remove game components from storage	Wardroom		15 sec		Selected game	Grasp components and remove	Visual, tactile Game is removed from storage	Damage to components Precludes normal set-up and game participation		
	Set-up game board	Wardroom		60 sec		Selected game is out of storage area	Attach board to restraint	Visual, tactile Board is stabilized	Bracket malfunction Game delayed or suspended		
	Game participation	Wardroom		--		Game rules	Throw darts at board	Visual, tactile Recreation and enjoyment from participation			

Figure 9-39. (Continued)

3. FACILITATE RECREATION

TASK ANALYSIS OF: PROVIDE FOR GROUP PASSIVE GAMES

SECOND-LEVEL FUNCTION NO: 3.2

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Open game storage compartment	Wardroom		15 sec		Schedule	Activate latch and open door	Visual, tactile	Latch malfunction	3/4-in. by 2-1/2-in. by 4-in. cards, 12-in. by 6-in. by 2-in. cover	
								Positive operating latch and door	Delay of game		
	Select game cards	Wardroom		25 sec		Display	Make selection	Visual, tactile	Nonavailability		
								Availability	Will affect recreation schedule		
	Remove cards from storage	Wardroom		15 sec		Selected game	Grasp pack of cards and remove	Visual, tactile	Damaged cards		
								Cards removed from stowage place	Delay of game or cancellation		
	Set up table	Wardroom		30 sec		Game equipment procured	Attach cover to table	Visual, tactilel	Improper setup		*Special cover and cards required to augment zero-g condition
								Cover attaches by velcro	Game is delayed		
	Take game positions or location	Wardroom		60 sec		Set up completed	Select partner if applicable	Visual, tactile	Wrong position on location		
								Face-to-face seating	Game is delayed		
	Fasten restraint	Wardroom		30 sec		Procedure	Activate latch and adjust	Visual, tactile	Restraint malfunction		
								Positive restraint for the game	Game delay		
	Game participating	Wardroom		--		Game rules	Play cards	Visual, tactile			
								Entertainment			

Figure 9-39. (Continued)

3. FACILITATE RECREATION

TASK ANALYSIS OF: PROVIDE PROJECTION CAPABILITY

SECOND-LEVEL FUNCTION NO: 3.3

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Open projector storage compartment	Wardroom		15 sec		Schedule	Activate latch and open door	Visual, tactile	Latch or door malfunction	7-in.-dia reel (16 mm); 14-in.-dia reel (16 mm)	
								Positive operating latch and door	Delay in projection		
	Remove projector from storage	Wardroom		30 sec		Storage compartment door open	Grasp handle of projector mount and pull	Visual, tactile	Mount malfunction		
								Projector mount swings out of storage compartment and locks in place	Delay in projection		
	Open film storage compartment	Wardroom		15 sec		Projector ready	Activate latch and open door	Visual, tactile	Latch or door malfunction		
								Positive operating latch and door	Delay in projection		
	Select film	Wardroom		30 sec		Perference	Film selection	Visual	Inadequate quantity and quality		
								Film availability	May affect crew morale		
	Remove film from storage	Wardroom		15 sec		Selection made	Grasp film roll and remove	Visual, tactile	Film damage		
								Film cannister comes out of compartment	Delay projection for repair, or select new film		
	Close film storage compartment door	Wardroom		5 sec		Film removed	Swing door to closed position	Visual, tactile, auditory	Latch malfunction		
								Door closes; latch activates positively	Delay projection		

Figure 9-39. (Continued)

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Thread film in projector	Wardroom		45 sec		Procedure	Place film in gate and activate switch	Visual, tactile	Film not threaded correctly		
								Film is ready for projection	Delay in projection		
	Set up movie screen	Wardroom		45 sec		Projector and film ready	Grasp handle and pull screen from storage tube	Visual, tactile	Mechanical failure		
								Spring-loaded roll-up tube with positive lock features	Delay in projection		
	Adjust lighting	Wardroom		30 sec		Screen set up and projector ready	Activate wardroom light switch to achieve desired light level	Visual	Switch malfunction		
								Ambient lighting dims to desired level for projection	Delay in projection		
	Project movie	Wardroom		--		Lights are dimmed	Turn on projector; power on switch, lamp on switch, sound on switch.	Auditory, visual, tactile	Projector malfunction		
								Movie projection begins	Delay in projection, possible schedule change		

Figure 9-39. (Continued)

TASK ANALYSIS OF: PROVIDE FOR GROUP CALISTHENICS

SECOND-LEVEL FUNCTION NO: 4.1

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Clear dining area	Wardroom		2 min		Schedule	Remove obstructions and clear the area of tables and chairs	Visual, tactile	Latch malfunction		Equipment should be designed so that only a minimum of change-over to clear the area is necessary
								Positive latch unit with quick release; Individual items are released.	Schedule delay or possible injury from bumping into furniture		
	Prepare equipment for storage	Wardroom		2 min		Table disconnected	Grasp at appropriate points and fold	Visual, tactile	Hinge/lock malfunction		
								Hinge mechanism; positive lock feature	Delay or possible failure to complete schedule		
	Store equipment	Wardroom		3 min		Table and chairs released from floor mounts	Place table in storage rack; stack chairs	Visual, tactile	Restraint/lock malfunction		
								Self-locking restraint actuates	Schedule delay		
	Set up personal restraints	Wardroom		5 min		Equipment stored	Attach restraints at appropriate points	Visual, tactile	Latch malfunction		
								Positive latch unit with quick release feature	Schedule delay		
	Participate in calisthenics	Wardroom		--		Exercise plan is initiated	Exercise	Physiological			All crew members must participate in the exercise program on a scheduled basis.
								Feeling of exertion	Failure to exercise will result in physical deterioration		

Figure 9-39. (Continued)

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Prepare exercise area	Wardroom	1 per 24 hr or as sched-uled	2 min		Schedule	Clear area for exercise equipment	Visual, tactile	Latch malfunction	Ergometer: 38 in. by 12 in. by 35 in.	Amount of area to be cleared depends on the equipment to be used, i.e., ergometer design and number to be set up
								Individual items of equipment are released			
	Prepare equip-ment for storage	Wardroom	1 per 24 hr or as sched-uled	2 min		Table and chairs disconnected	Grasp table at appropriate points and fold	Visual, tactile	Hinge / lock malfunction		
								Hinge mechanism with positive lock feature	Schedule delay		
	Store equipment	Wardroom	1 per 24 hr or as sched-uled	3 min		Table folded and chairs stacked	Place in storage racks	Visual, tactile	Restraint/lock malfunction		Furniture must not float about loose due to the risk of injury or damage to equipment
								Self-locking restraint actuates holding furniture	Schedule delay, damage to other equipment		
	Set up ergometer	Wardroom	1 per 24 hr or as sched-uled	3 min		Equipment stored	Attach restraint at appropriate points	Visual, tactile	Restraint attachment malfunction		
								Positive lock mechanism with quick-release feature attaches ergometer securely	Schedule delay		
	Exercise	Wardroom	1 per 24 hr or as sched-uled	--		Schedule or individual desire	Exercise	Visual, tactile			Individual needs vary widely providing design requirements for the implementa-tion of a planned exercise program while providing opportunity for those who wish to exceed the plan
								Physiological conditioning need is satisfied or scheduled plan is completed	Failure to exercise will affect physical condition, could limit mission		

Figure 9-39. (Continued)

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Prepare area for sports	Wardroom	I each 24 hr or as desired	2 min		Schedule or group agreement	Clear area for sports	Visual, tactile Individual items of equipment are released	Release malfunctions Equipment cannot be moved, eliminating sports or posing a hazard	Volume: 9 ft by 15 ft by 6.5 ft	Equipment must be designed to permit easy and rapid clearing of the area
	Prepare equipment for storage	Wardroom		2 min		Tables and chairs disconnected	Fold table	Visual, tactile Table folds for stowing. Mechanism actuates providing lock	Equipment cannot be stowed Sports cannot be played if area can't be cleared		
	Store furniture	Wardroom		3 min		Tables folded and chairs stacked	Place furniture in restraints	Visual, tactile Restraint actuates holding furniture in place	Restraint malfunctions Furniture free floating presents a hazard		
	Set up sports equipment	Wardroom		3 min		Area is clear	Set up and attach appropriate sports equipment	Visual, tactile Equipment is ready for use	Equipment malfunction Reduced level or no sports		Equipment must be easily erected and taken down. Quick release fasteners used throughout
	Participate in sports	Wardroom		0 to 2 hr		Equipment installed and ready for use	Play the designated sport	Visual, tactile Group participation	Disinterest, injuries, or restrictive schedule Conditioning and morale may suffer		Specific sports are not yet defined for zero-g. Modifications to earth sports may result in: Ball games Tumbling Trampoline

Figure 9-39. (Continued)

5: PROVIDE MEDICAL CARE

TASK ANALYSIS OF. PROVIDE MEDICAL PERSONNEL
SECOND-LEVEL FUNCTI

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Medical examination	Wardroom	Scheduled 1 each month	4 hr		Schedule	Complete physical examination including biological analysis	Visual, tactile, auditory	Failure to take examination	Facility 10 ft by 12 ft by 6.5 ft 780 cu ft volume. Equipment volume: 30 cu ft.	
								Condition of patient including laboratory analysis	Possible health hazards may affect mission completion		
	Medical treatment	Wardroom	Random	15 min		Crewman requiring aid	Diagnosis of symptoms displayed by patient	Visual, tactile auditory	No response to treatment	Medical supplies and instrumentation	Patient may occupy this area for extended periods of time
								Patient response to treatment. Findings of laboratory analysis	Possible mission abort		

Figure 9-39. (Continued)

6.0 ASSEMBLE CREW

TASK ANALYSIS OF: PROVIDE RESTRAINT

SECOND LEVEL FUNCTION NO: 6.1

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Translate to Wardroom	Wardroom	Random	3 to 5 min		Schedule or directive	Assemble in wardroom without delay and locate restraint	All	Restraint not available	Restraint for all crew members (seat with belt)	
								Seat located	Disruption of assembly		
	Position seat	Wardroom	Random	1 min		Seat located	Move restraint to most advantageous position	Audio, visual, tactile	Can't see or hear		A seat is required for each crewman (12)
								Good position for observing presentation	Information may be missed		
	Fasten restraint	Wardroom	Random	30 sec		Seat is in position for viewing	Take comfortable seated position and fasten restraint	Audio, visual, tactile	No restraint		A restraint is required for each crewman of the relief crew (12)
								Body is restrained for listening and viewing assembly	Disruption		

Figure 9-39. (Continued)

6 0 ASSEMBLE CREW

TASK ANALYSIS OF: PRESENT AUDIOVISUAL INFORMATION

SECOND LEVEL FUNCTION NO. 6.2

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Observe visual aids	Wardroom				Program is started	Observe and perceive visual information from movies, slides, charts, etc.	Visual	Equipment malfunction	Projection equipment and screen	
								Unobstructed and uninterrupted flow of visual information	Information flow is severely restricted		
	Listen to audio information	Wardroom				Program commences	Receive audio information that either augments or complements visual information	Audio	Equipment malfunction	Sound system with speakers placed for all to hear	Acoustical control will be required in circular rooms
								Audible and intelligible information flow	Lack of sound restricts or eliminates information flow		

Figure 9-39. (Continued)

6.0 ASSEMBLE CREW

TASK ANALYSIS OF:: VARY ILLUMINATION

SECOND-LEVEL FUNCTION NO: 6.3

NO.	TASK DESCRIPTION	LOCATION	FREQ	TIME	SKILL	INPUT	DECISION	FEEDBACK	PERFORMANCE DEVIATION	ADDITIONAL EQUIPMENT	REMARKS
	Dim lights	Wardroom	Random			Projection materials ready for viewing	Reduce light level to comfort range for viewing projected materials	Visual	Lights will not dim	Dimming device on lights	
								Ambient lighting augments projected material	Difficult or impossible to view projected aids		

Figure 9-39. (Continued)

SECTION 10

CONCLUSIONS

10

CONCLUSIONS

To enhance crew performance during long-duration missions, spacecraft interiors should be designed to create feelings of well being. Efficiency will suffer if the crew is dissatisfied with any aspect of the surroundings. Every effort must be made, therefore, to design an interior that is appealing to the crew, is sufficiently flexible to allow crew members to make changes based on individual preferences, and provides for programmed changes in spacecraft systems to vary the overall environment. Crew members can change their environment by altering the intensity and color of the lighting and by closing or opening the compartment doors to control sound and privacy. If space is important, two men can share a larger cubicle by removing the partition, which doubles the usable volume (fig. 10-1). Sexual and cultural differences must also be included in the design rationale because future spacecraft probably will carry female crew members and/or multi-nation crews. Instead of forcing the crew to adapt to an existing spacecraft, individual differences should be planned for in advance and provided for in the basic interior design of the spacecraft.

The entire interior should be soft for crew protection during zero-g flight. Traction devices, hand holds, and restraints should be included in the basic design so that these will not have to be added later. As a result, unhandy and unsafe protruberances can be eliminated and overall weight reduced.

Multipurpose areas such as the wardroom should be designed to minimize the equipment changes required for performing different functions. Ideally, there should be no multifunction areas. The decision on such areas, however, must be based on a tradeoff between importance of function, spacecraft size and weight, and amount of use.

Leisure time activities are expected to assume an increasingly important role as mission duration increases, and new and creative solutions are required to eliminate boredom. Tailoring the leisure materials to suit the tastes and desires of the crew will help to eliminate undesired items and result in efficient use of space and weight. Much additional study in this complex area must be performed before meaningful criteria and standards can be established for use in spacecraft design.

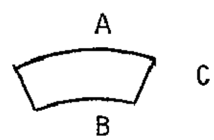
Spacecraft interior arrangement and equipment must be the result of creatively integrating current scientific data with mission requirements to achieve an environment that is pleasing to the crew. Since this achievement is extremely complex and requires consideration of many variables, especially when considering female crew members and personnel of differing cultural backgrounds, these decisions cannot result from personal designer beliefs. Although a number of interior styles might be successful for short-duration missions, long-duration mission design must be based on the comprehensive integration of the most current concepts in psychology, physiology, sociology, technology, and art.

A scale model was built (3/4 in. = 1 ft) to show the three-dimensional relationship of the areas (fig. 10-2), the flexibility of the sleep area (fig. 10-3), and the wardroom and hygiene area (fig. 10-4). Design criteria are included for each compartment in the report sections dealing with each specific compartment; these should be used in conjunction with the functions and task analyses. Recommended volumes for each of the compartments are shown in table 10-1. The volumes consist of minimum areas and the fixed 78-in. ceiling height. Locating these areas in curved floor plans requires caution concerning aisle space and the traffic flow through the compartment. This comprehensive approach to spacecraft design is an important beginning, but much study remains to be done, especially for weightlessness and mobility. Appropriate concepts must be developed and tested to ensure habitability for long-duration missions.

TABLE 10-1

AREAS AND VOLUMES RECOMMENDED FOR COMPARTMENTS

Compartments	Area, sq ft	Volume, cu ft	Rectangular Dimensions	Circular Dimensions*			Arc Length, deg
				A	B	C	
Sleep	37.5	243.75	7 ft, 6 in. by 5 ft	-	-	-	30**
Wardroom	241	1566.5	10 ft by 24 ft, 1 in.	32.9	10.9	10	126
Hygiene	181.13	1177.3	10 ft by 18 ft, 1 in.	27.3	9.2	10	104

*


**A 30-deg arc length provides greater dimensions than those listed. However, usability of area is compromised if arc length results in areas of 37.5 sq ft or less.

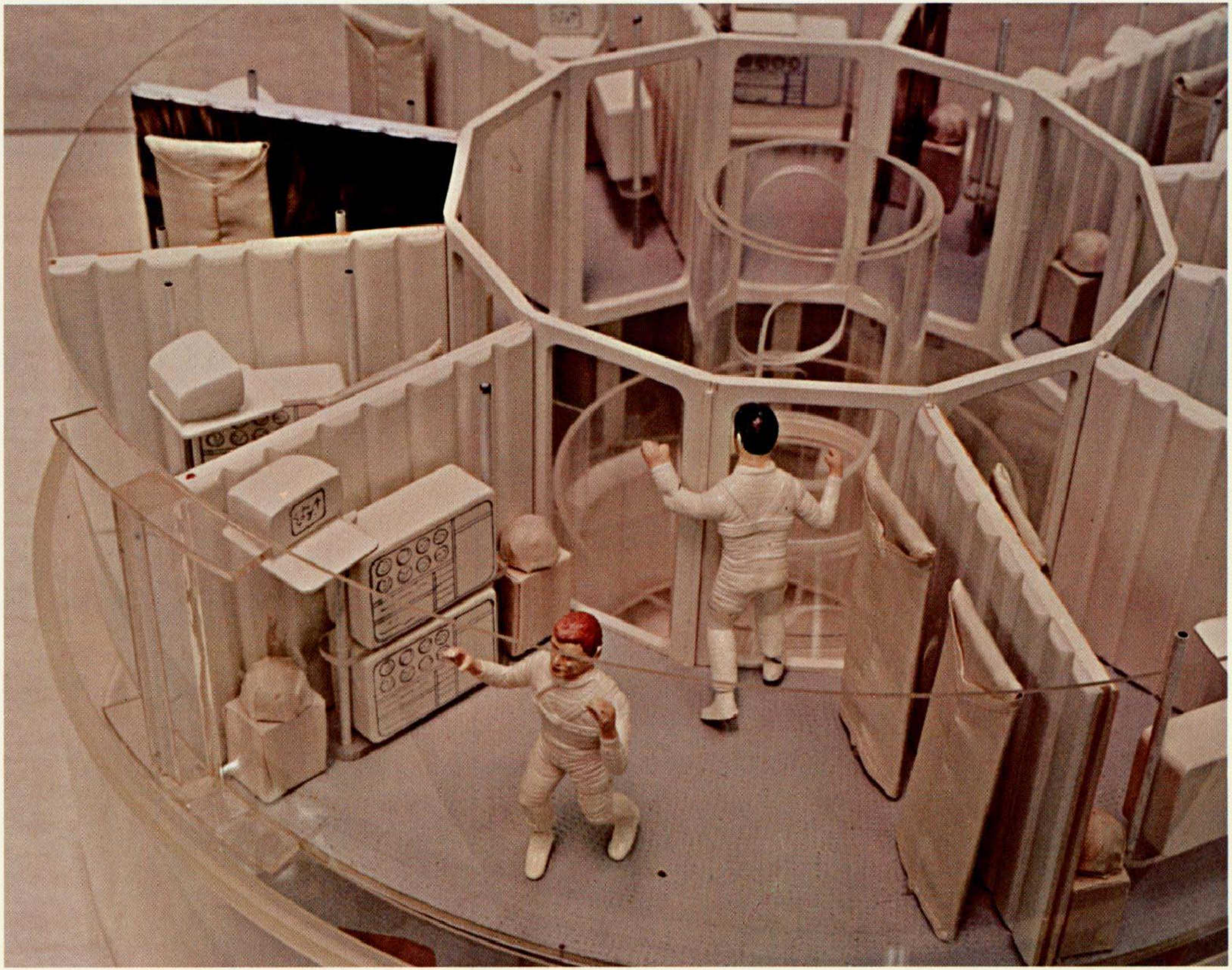


Figure 10-1. Sleep Area with Partition Removed

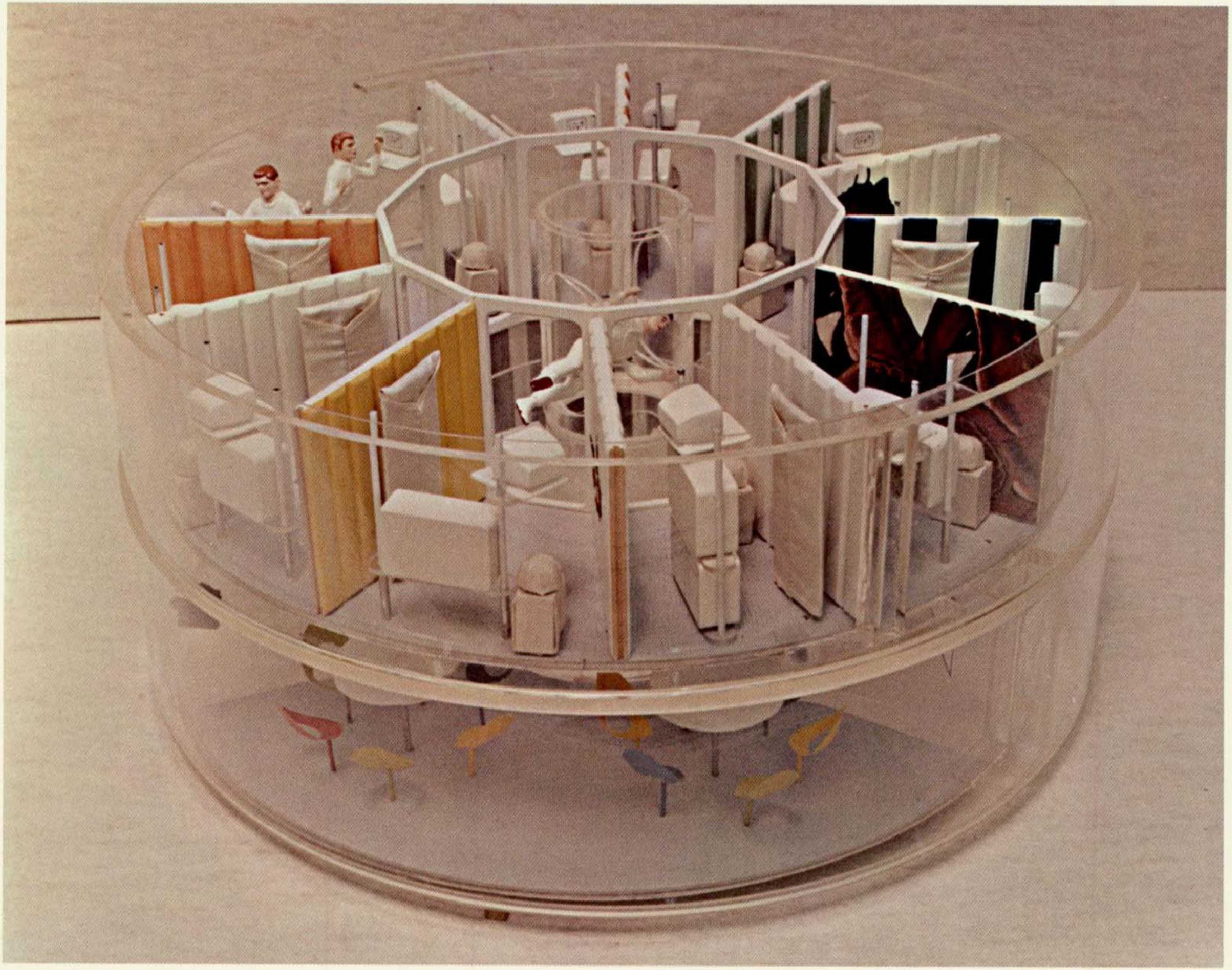


Figure 10-2. Compartment Relationships

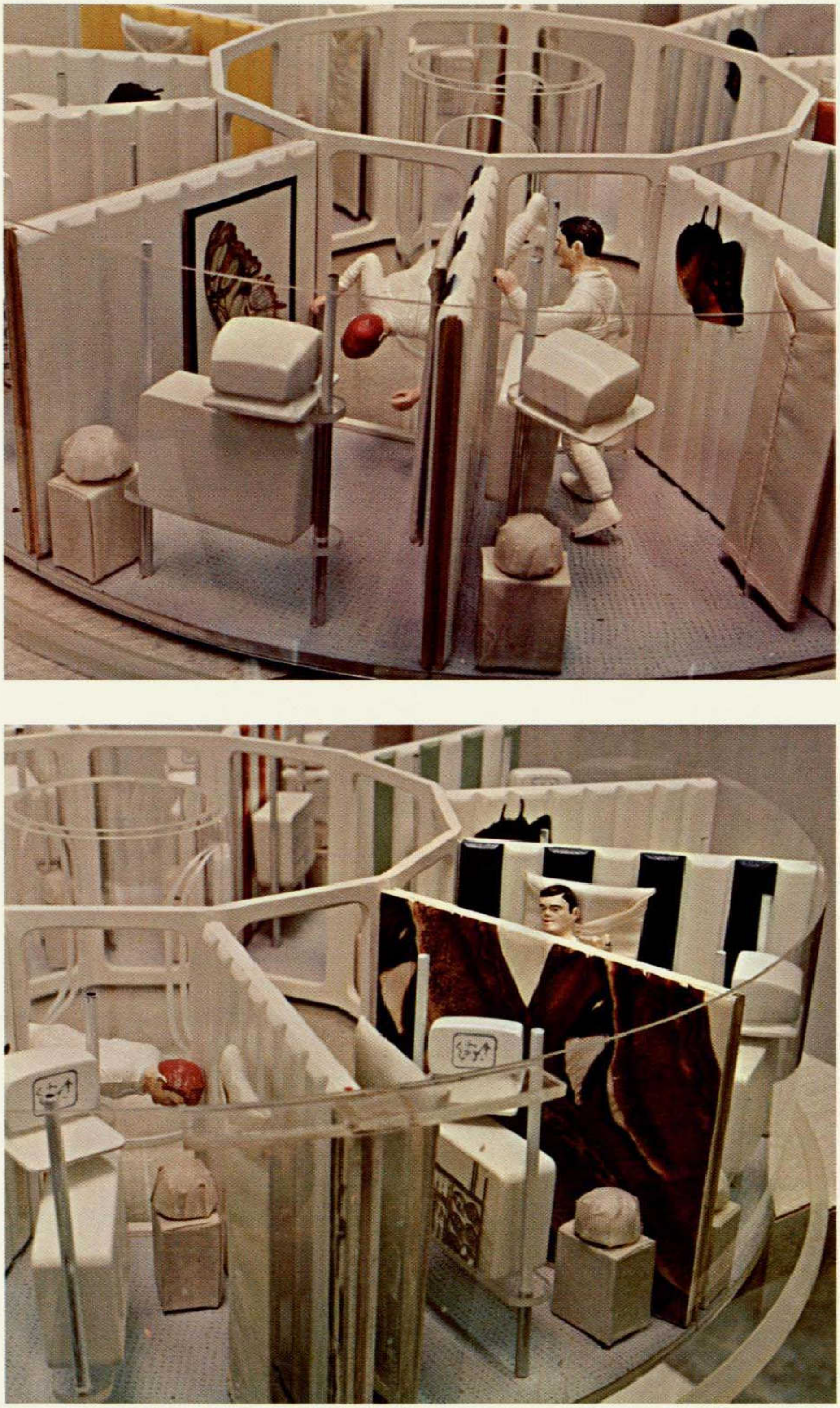


Figure 10-3. Flexibility of Sleep Area

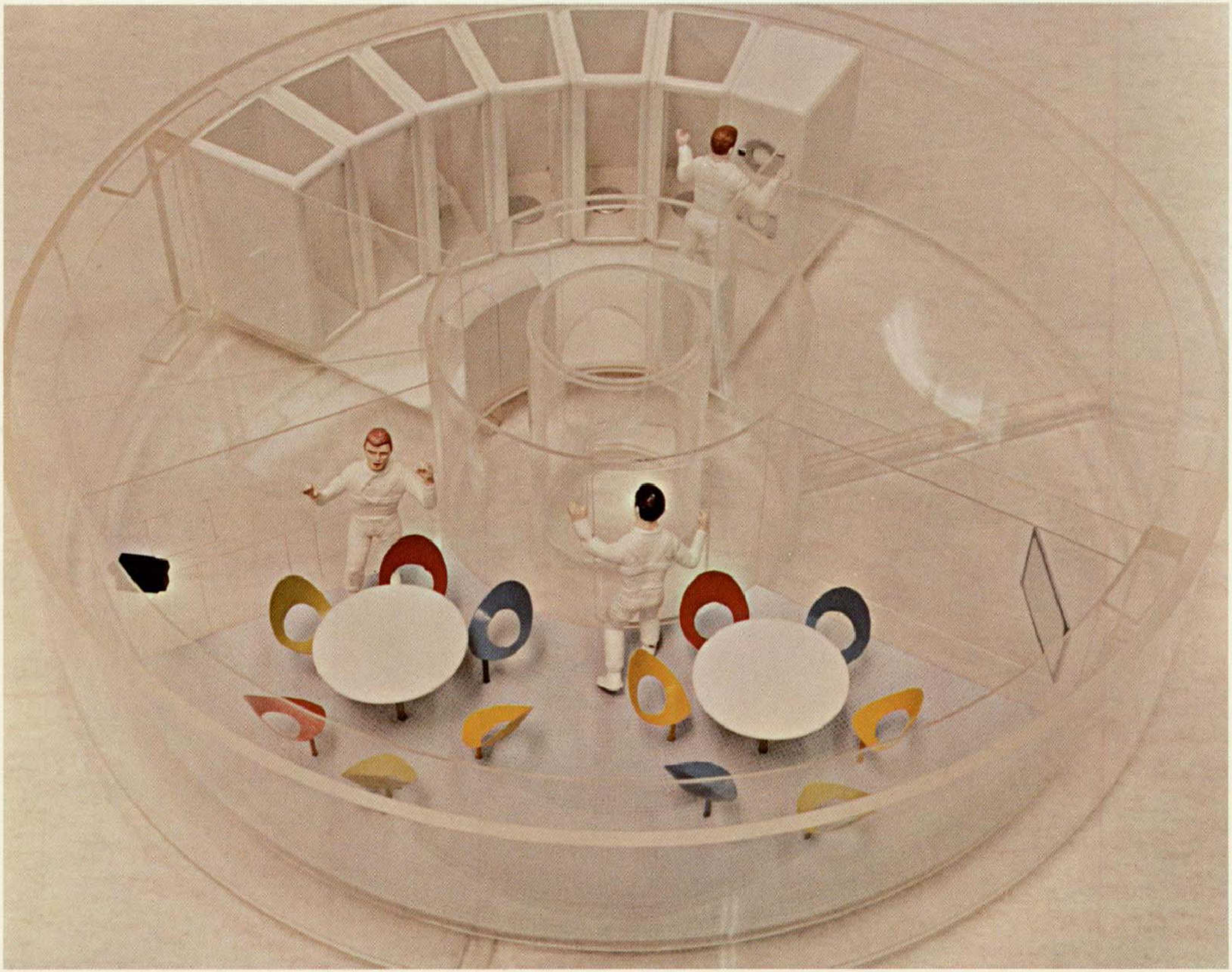


Figure 10-4. Wardroom and Hygiene Area

APPENDIXES

APPENDIX A

AN ANALYTIC STRUCTURE FOR EVALUATING HABITABILITY

Habitability of a space or area, for the purposes of this analysis, is considered a function of the responses of one or more persons attempting to perform behaviors within that particular space in a given period of time. In this context, the habitability of a specific space must be defined by the requirements of the individuals housed within the space to fulfill their mission. Habitability, therefore, is a function of the interaction between (1) the patterns of requirements for mission fulfillment, life support, and psycho-social maintenance, and (2) the physical and temporal characteristics of the space involved.

Since the number of considerations involved with the habitability evaluation of a given space is so great, it is important to evolve an analytic structure that will allow the manifold dimensions to be evaluated. This discussion presents a mode of conceptualizing habitability in terms of the man, the mission, and the space. Operationalization of the dimensions must follow so that empirical evidence can be obtained on the specific trade-offs that can be considered feasible for a given mission.

DEFINITIONS

Within this discussion, a number of terms have somewhat specialized definitions. These terms are defined below.

<u>Mission</u>--The imposed requirements for behavior, placed upon the actors by an external source, which stand as the primary reasons for the overall sequence of behavior episodes.

<u>Actor</u>-- One of the human participants in the mission fulfillment situation.

<u>Action</u>-- A behavior or act with a commonly identifiable meaning. Example: eating, defecating, reading.

<u>Behavior episode</u>--A collection of actions that together have meaning as a totality. Example: Deciding to perform an act, the performance, and the cognition of effects thereof. An EVA performance, checkout of an onboard subsystem, etc.

<u>Constraint</u>--A behavior-limiting circumstance such as a mission requirement, a life-support requirement, or a social relations consideration. Constraints, taken together, define the behavior control system, as differentiated from a theoretical, random behavior model.

BEHAVIOR MODEL

The term environment is currently used in a large number of contexts with many different connotations. In this discussion, the term environment has a specific meaning that is derived from the primitive terms defined above. This behavior model for environment will assist in the definition of habitability by allowing a specification of the environment (envelope) in which the individual is embedded and to which he responds either favorably or unfavorably.

The Behavior Grid

Acts, or behaviors, are performed by actors. The distribution of acts by actors can be thought of as a two-dimensional grid, with the specific act on one axis and the specific actors on the other. Such a grid, as a matrix of ones and zeros, depicts or maps the behavior repertory of the crew as a collective body, essentially showing who does what.

The Behavior Matrix

The behavior grid alone presents only a portion of the mapping required to depict actual behavior patterns. All actions of interest in this study occupy space and time. By adding these considerations to those of the grid, a solid matrix is defined that identifies the distributions of acts, performed by actors, in particular space and particular time.

Behavioral Constraints

It is clear that human behaviors do not become elicited in random patterns. A huge variety of influences modify the occurrence, sequence, periodicity, and repetitions of actions. As noted above, these influences are termed constraints in this discussion. A four-fold typology of constraints can be developed to account for all forms of systematic influence upon the actors and their behavior. These are:

(1) <u>Personal constraints</u>: Psychological profile, individual capability, etc.

(2) <u>Social constraints</u>: Role, status within the crew social system, folkways, laws, mores, customs.

(3) <u>Spatial constraints</u>: Space and area requirements of behaviors.

(4) <u>Temporal constraints</u>: Time requirements.

The constraints upon behavior for any individual, and for any collective entity, arise from both individual and collective sources. Such divergent origins as childhood experiences, antipathies, superstitions, self-concept, and

organizational responsibility contribute to the kinds of constraints that affect the qualitative and quantitative characteristics of behavior patterns and their effects upon the actor and others.

A Definition of Environment

Using the behavior matrix and constraint system described above, it is possible now to define the term environment. For these studies of habitability, environment is considered as the psycho-social-spatial-temporal envelope in which a specific group or crew is behaving or acting. That envelope, in turn, is defined by the patterns of behavior constraints acting upon the behavior matrix. Thus, through application of the model, the environment becomes a dynamic resultant of the configuration of specific individuals, mission, psycho-social characteristics, physical surroundings, and time schedule. Change in any of these circumstances implies a change in the environment.

Habitability as a Response to Environment

Given the above definition of environment, the different responses to the environment by the various individuals within the envelope can be considered. Such responses, inasmuch as they define evaluation of the environment by the individuals, represent the degree of habitability of a mission-man-environment complex. Since each actor interprets his environment through his own cognitive system, habitability cannot be considered a unit characteristic of the spatial configuration alone, but rather as an interactive process, differing for each individual, and changing as requirements for behavior and the capability of the environment to support the behavior episodes are altered.

THE ACTIVITY PROFILE

To provide for a systematic analysis of crew member activities for which the habitability responses can be considered crucial, a four-way classification is useful:

(1) Duty Activities: Mission-oriented behavior and requirements therefor.

(2) Leisure Activities: Personal-oriented behavior and requirements therefor.

(3) Sleep Activities: All non-waking behavior, and preparations therefor.

(4) Body Function Activities: Eating, elimination, respiration, and management of these functions.

For activities in each of these areas, a considerable number of shared expectations are held by crew members for the manner in which behavior episodes in each area will be required and ultimately performed. Based on the analytic

structure developed here, the habitability of a space is a function of the degree to which system-imposed requirements for behavior can be fulfilled within the context of personal and group restraints upon performance of the necessary behavior episodes. Reduced to simplest terms, then, the current concept of habitability is one that posits habitability as the result of how an environment is supportive to an individual's needs for behavior in areas of duty, leisure, sleep, and body function. An area of space that allows fulfillment of behavioral requirements within the system of constraints with a minimum of disruption or conflict between those constraints, as perceived by the individual, may be said to be habitable.

This phenomenological concept of habitability implies a number of issues concerning habitability that are also worthy of note. First, it is clear that in a multi-man crew, habitability can differ between individuals, for the same space and same mission requirements. In addition, as the set of expectations held by crew members for early-program missions is altered for later-program missions, habitability will change, generally in the direction of greater dissatisfaction.

Perhaps the most important implication of a phenomenological perspective on habitability is the notion that crew personnel may be trained in such a manner that their response to behavior constraints and fulfillment of expectations will lead to a perception of heightened (or maintained) habitability of their area or space.

MEASUREMENT OF HABITABILITY

The analytic structure developed here provides the basis for the formulation of measurement procedures for determination of habitability response to various man-mission-space configurations.

APPENDIX B

HABITAT ATTITUDE MEASUREMENT

General attitudes of each individual toward the habitat can be measured by the habitat atmosphere scale and the semantic differential scales presented as Parts 1 and 2, respectively, of this appendix.

PART I

HABITAT ATMOSPHERE SCALE

Please decide which of the following statements are true of your habitat and which are not. Mark those that are true with a T, those that are not with an F.

1. This is a lively habitat.
2. Inhabitants can wear what they want.
3. Inhabitants tend to hide their feelings from one another.
4. There are groups of inhabitants who hang around together a lot.
5. Inhabitants tend to look messy.
6. Inhabitants tell each other about their personal problems.
7. It's hard to get people to argue around here.
8. Inhabitants don't order each other around.
9. Most inhabitants follow a regular schedule each day.
10. Inhabitants talk very little about their pasts.
11. The food here is the best I've ever tasted.
12. Inhabitants put a lot of energy into what they do around here.
13. Inhabitants sometimes play practical jokes on each other.
14. There is no organized form of government in this habitat.
15. Inhabitants set up their own activities without being prodded by anyone.
16. Inhabitants have very little time to encourage each other.
17. Most inhabitants are more concerned with the past than the future.
18. The habitat has very few social activities.
19. Inhabitants activities are carefully planned.
20. Inhabitants hardly ever discuss their sexual lives.
21. This is the best place I've ever been.

22. The habitants are proud of this habitat.

23. Inhabitants often gripe.

24. Things are sometimes very disorganized around here.

25. Inhabitants act on other inhabitants' suggestions.

26. When inhabitants disagree with each other, they keep it to themselves.

27. Inhabitants know what other inhabitants want.

28. Inhabitants are expected to work toward their goals.

29. In this habitat, everyone knows who's in charge.

30. The inhabitants' rooms are often messy.

31. Personal problems are openly talked about.

32. Very few things around here ever get people excited.

33. The habitat always stays just about the same.

34. If an inhabitant breaks a rule, he knows what will happen to him.

35. Very few inhabitants have any responsibility in this habitat.

36. Inhabitants say anything they want to each other.

37. Inhabitants rarely help each other.

38. This is a very well organized habitat.

39. Discussions are pretty interesting in this habitat.

40. Inhabitants often joke about or critize each other.

41. People are always changing their minds here.

42. Inhabitants can leave the habitat without saying where they are going.

43. It is hard to tell how inhabitants are feeling in this habitat.

44. Inhabitants are encouraged to plan for the future.

45. Inhabitants who break habitat rules are punished for it.

46. Inhabitants often do things together on the weekends.

47. The habitat sometimes gets very messy.

48. Nobody ever volunteers around here.

49. People in this habitat rarely argue.

50. There is very little to do around here over the week-ends.

51. Inhabitants rarely give in to pressure from other inhabitants.

52. It's OK to act crazy around here.

53. There is very little sharing among the inhabitants.

54. The inhabitants rarely talk about their personal problems with each other.

55. Inhabitants are pretty busy all of the time.

56. In this habitat it is a healthy thing to argue.

57. The habitat is quite different at night than during the day.

58. All inhabitants are expected to take some leadership at times.

59. Each inhabitant is treated differently here.

60. Inhabitants are encouraged to learn new ways of doing things.

61. The social and recreation areas are often messy.

62. Inhabitants are expected to share their personal problems with each other.

63. The inhabitants don't really know their roles.

64. Inhabitants don't do anything unless asked.

65. Inhabitants here rarely become angry.

66. Inhabitants are encouraged to show their feelings.

67. Inhabitants care more about how others feel than their practical problems.

68. The habitat rules are always changing.

69. Inhabitants in this habitat care about each other.

70. There is very little group spirit in this habitat.

71. If an inhabitant argues with another, he will get into trouble for it.

72. Habitat rules are clearly understood by the inhabitants.

73. The inhabitants discourage criticism of themselves.

74. This is a habitat ready for spontaneity.

75. This is a supportive habitat.

76. This is a habitat that is quite practical.

77. Inhabitants like each other here.

78. This is an orderly habitat.

79. This habitat encourages insight into oneself.

80. This habitat is one where people get very involved in what they do.

81. This habitat is permissive of aggression.

82. There is room for a good deal of variety in this habitat.

83. People in this habitat are pretty clear about what they are doing.

84. At least some of the inhabitants here are encouraged to be submissive.

85. Inhabitants here have a lot of autonomy.

(Adapted From Moos, 1969)

Scoring:

Spontaneity includes items 3F, 15T, 26F, 36T, 42T, 43F, 52T, 66T, 74T

Support includes 16F, 27T, 37F, 59T, 75T

Practicality includes 17F, 28T, 44T, 60T, 67F, 76T

Affiliation includes 4T, 18F, 46T, 53F, 69T, 77T

Order includes 5F, 9T, 14F, 19T, 30F, 38T, 47F, 61F, 78T

Insight includes 6T, 10F, 20F, 31T, 54F, 62T, 79T

Involvement includes 12T, 22T, 32F, 39T, 48F, 55T, 64F, 70F, 80T

Aggression includes 7F, 13T, 23T, 40T, 49F, 56T, 65F, 71F, 81T

Variety includes 1T, 33F, 50F, 57T, 68T, 82T

Clarity includes 8F, 24F, 34T, 41F, 63F, 72T, 83T

Submission includes 29T, 45T, 84T

Autonomy includes 2T, 25T, 35F, 51F, 58T, 73T, 85T

Response set includes 11T, 21T

PART 2

SEMANTIC DIFFERENTIAL SCALES

I.D. or Name ____________

Date: ____________

Time: ____________

Please rate the following items on the scales below the items. Your first reaction is best; do not worry if the relationship between the scale and the items is not logically clear; use intuition; it's all right if the rating doesn't seem to make much sense. Place a check over the appropriate part on each scale.

THE FOOD HERE

	A Lot	A Little	A Little	A lot	
Weak					Strong
Nice					Awful
Hot					Cold
Good					Bad
Fast					Slow
Ugly					Beautiful
Sad					Happy
Small					Big

SLEEPING HERE

	A Lot	A Little	A Little	A Lot	
Weak					Strong
Nice					Awful
Hot					Cold
Good					Bad

SLEEPING HERE (Continued)

	A Lot	A Little	A Little	A Lot	
Fast					Slow
Ugly					Beautiful
Sad					Happy
Small					Big

IN-HABITAT WORK

	A Lot	A Little	A Little	A Lot	
Weak					Strong
Nice					Awful
Hot					Cold
Good					Bad
Fast					Slow
Ugly					Beautiful
Sad					Happy
Small					Big

EXTRA-HABITAT WORK

	A Lot	A Little	A Little	A Lot	
Weak					Strong
Nice					Awful
Hot					Cold
Good					Bad
Fast					Slow
Ugly					Beautiful

EXTRA-HABITAT (Continued)

	A Lot	A Little	A Little	A Lot	
Sad					Happy
Small					Big

HYGIENE HERE
(Body Cleaning, Waste Elimination, Medical, and Health Facilities)

	A Lot	A Little	A Little	A Lot	
Weak					Strong
Nice					Awful
Hot					Cold
Good					Bad
Fast					Slow
Ugly					Beautiful
Sad					Happy
Small					Big

RECREATION HERE

	A Lot	A Little	A Little	A Lot	
Weak					Strong
Nice					Awful
Hot					Cold
Good					Bad
Fast					Slow
Ugly					Beautiful
Sad					Happy
Small					Big

MYSELF AS I AM HERE

	A Lot	A Little	A Little	A Lot	
Weak					Strong
Nice					Awful
Hot					Cold
Good					Bad
Fast					Slow
Ugly					Beautiful
Sad					Happy
Small					Big

THIS HABITAT

	A Lot	A Little	A Little	A Lot	
Weak					Strong
Nice					Awful
Hot					Cold
Good					Bad
Fast					Slow
Ugly					Beautiful
Sad					Happy
Small					Big

Please rate these same items according to your evaluation at this time of their importance to overall mission success, crew compatibility, and doing one's assigned jobs well. Please check over the appropriate place on each scale.

THE FOOD HERE

Not very important to mission success	Somewhat important	Extremely important
Not very important to crew compatibility	Somewhat important	Extremely important
Not very important to doing our work well	Somewhat important	Extremely important

MYSELF AS I AM HERE

Not very important to mission success	Somewhat important	Extremely important
Not very important to crew compatibility	Somewhat important	Extremely important
Not very important to doing our work well	Somewhat important	Extremely important

SLEEPING HERE

Not very important to mission success	Somewhat important	Extremely important
Not very important to crew compatibility	Somewhat important	Extremely important
Not very important to doing our work well	Somewhat important	Extremely important

IN-HABITAT WORK

Not very important to mission success	Somewhat important	Extremely important
Not very important to crew compatibility	Somewhat important	Extremely important
Not very important to doing our work well	Somewhat important	Extremely important

EXTRA-HABITAT WORK

Not very important to mission success	Somewhat important	Extremely important
Not very important to crew compatibility	Somewhat important	Extremely important
Not very important to doing our work well	Somewhat important	Extremely important

THIS HABITAT

Not very important to mission success	Somewhat important	Extremely important
Not very important to crew compatibility	Somewhat important	Extremely important
Not very important to doing our work well	Somewhat important	Extremely important

HYGIENE HERE

Not very important to mission success	Somewhat important	Extremely important
Not very important to crew compatibility	Somewhat important	Extremely important
Not very important to doing our work well	Somewhat important	Extremely important

RECREATION HERE

Not very important to mission success	Somewhat important	Extremely important
Not very important to crew compatibility	Somewhat important	Extremely important
Not very important to doing our work well	Somewhat important	Extremely important

APPENDIX C

INTERPERSONAL DIAGNOSTIC REPORT

Level of social interaction will not be scored directly by the observers at the time of the study. Instead, a recording should be made of social interaction every day at the same time. The recording apparatus (preferably a video tape machine, otherwise a tape recorder) should be turned on every evening with supper time, left on for an hour and a half, and then turned off. The tape made should then be labeled with the date, time turned on, and time turned off. Comments on anything that made the day unusual or special should also be noted. The social behavior recorded will then be analyzed by trained observers using the interpersonal diagnostic report, and may also be analyzed by computer using the General Inquirer content analysis system.

The interpersonal behavior that has been recorded for each day will be broken down into behavior units, or instances of single behavioral mechanisms or reflexes. Note that such behaviors can involve varying lengths of time. Subsequently, each unit will be rated according to type of social interaction and intensity. The rating form would look something like this:

Man ID	Unit Code	Intensity

Unit code: there are sixteen types of behavioral units:

(1) Managerial-autocratic behavior, showing elements of power, leadership, command, direction, or authority, provoking obedience; in less intense form, managing, directing, leading; in more intense form, dominating, bossing, ordering.

(2) Competitive-narcissistic behavior, showing elements of narcissism, independence, self-expression, superiority, or power struggle, provoking inferiority; in less intense form confident, independent actions; in more intense form, boasting, acting proudly and being narcissistically exhibitionistic.

(3) Competitive-narcissistic behaviors, showing elements of exploitation, seduction, selfishness, keeping to self, depriving, rejecting, provoking distrust; in less intense form competing and acting assertively; in more intense form, exploiting, withholding, and rejecting.

(4) Aggressive-sadistic behaviors, showing elements of punishment, coercion, threat, quarreling, or brutality, provoking passive resistance; in less intense forms, aggressive, firm actions; in more intense forms, punitive, sarcastic, or unkind actions.

(5) Aggressive-sadistic behaviors, showing elements of pure hostility, disaffiliation, anger, fighting, murder, provoking hostility; in less intense form, frank, forthright, critical actions; in more intense forms, attack or unfriendly actions.

(6) Rebellious-distrustful behaviors, showing elements of unconvential activity, passive resistance, rebellion, crime against authority, jealousy, drunkenness, covert stealing, taking offense, or bitterness, provoking punishment; in less intense form, realistic and justified rebellion or mildly unconventional actions; in more intense form bitter, rebellious actions and strong complaint.

(7) Rebellious-distrustful behaviors, showing elements of deprivation, distrust, disappointment, rejectedness, suspicion, or having bad things done to one, provoking rejection; in less intense form, realistic wariness or skepticism; in more intense form, acting hurt, suspicious, or distrustful.

(8) Self-effacing-masochistic behaviors, showing elements of masochism, grief, self-destruction, withdrawal, guilt, self-punishment, loneliness, running away, fear, anxiety, provoking punishment intentionally and also provoking arrogance; in less intense forms, shy, sensitive, modest actions; in more intense forms, self-condemnnation and anxious, guilty, self-effacing actions.

(9) Self-effacing-masochistic behaviors, showing elements of weakness, obedience, submission, indecision, ambivalence, immobilization, unconsciousness, passivity, illness, provoking leadership; in less intense forms, obeying and doing one's duty; in more intense forms weak and spineless acts and submission.

(10) Docile-dependent behaviors, showing elements of conformity, accepting advice, positive passivity, docility, following, being student, provoking advice; in less intense forms, conforming, admiring, and respecting; in more intense forms docile conformity and overrespectful actions.

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(11) Docile-dependent behaviors, showing elements of trust, clinging, dependence, having good things happen to one, being taken care of, gratitude, provoking help; in less intense forms, trusting and asking for help; in more intense forms clinging, begging, depending upon.

(12) Cooperative-overconventional behaviors, showing elements of collaboration, agreeability, congeniality, working things out, adjustment in general, provoking tenderness; in less intense forms, cooperating, participating, agreeing; in more intense forms agreeing at all times, compromising, being overconventional.

(13) Cooperative-overconventional behaviors, showing elements of love, affiliation, friendship, provoking love; in less intense forms, friendly, affectionate actions; in more intense forms effusive actions and seeking friendly feelings from others.

(14) Responsible-hypernormal behaviors, showing elements of support, tenderness, kindness, encouragement, solace, pity, provoking acceptance; in less intense forms, treating gently, supporting, sympathizing; in more intense forms soft-hearted behavior, pitying, doting upon.

(15) Responsible-hypernormal behaviors, showing elements of generosity, help, curing, giving, taking care of, provoking trust; in less intense forms, helping, offering, giving; in more intense forms, taking responsibility compulsively, hypernormal activity.

(16) Managerial-autocratic behaviors, showing elements of success, heroism, popularity, acclaim, achievement, wisdom, teaching, explaining, provoking respect; in less intense forms, guiding, advising, teaching; in more intense forms, seeking respect compulsively, pedantic and dogmatic actions.

<u>Intensity code</u>: Intensity should be scored

(1) Very mild or low intensity.

(2) Mild but clear.

(3) Clearly and plainly and rather strongly.

(4) Intense and strong.

Further directions for the intensity code are given in the explanation of the unit code.

At least two observers should score every behavioral recording; as indicated earlier, these will not be the same observers as used during the habitability test monitoring.

APPENDIX D

HABITAT ASSESSMENT RATING SCALES

Three rating scales were developed to provide assessment of the habitat. The first, presented in Part I of this appendix, is a scale designed to rate 82 basic items common to most habitats as these items contribute to the quality of life for the residents of the habitat.

The second, Part 2 of this appendix, conbines five scales that can be used to indicate the degree of sensible variety in the habitat. An overall environmental assessment can be indicated on the rating charts presented as Part 3.

PART I

BASIC ITEMS IN HABITAT

Use the following scale* for rating the basic items in your habitat, or the habitat that you are observing:

5 = superlative, considerably better than ordinary, and definitely leading to excellent habitability

4 = very good, better than average, leading to above normal habitability

3 = ordinary, just about what one would expect in the average habitat, helpful in maintaining the quality of life but not in improving it

2 = poor, below average, in some ways injurious to quality of life in the habitat

1 = very poor, far below what one expect in the ordinary habitat, detrimental to quality of life in the habitat

Thus ratings of 4 and 5 are used when a particular aspect of the item is better than ordinary, and ratings of 2 and 1 are for use when it is below the ordinary standard.

For example, if one were rating the furniture used during eating in the habitat, the first aspect to be rated would be: does it perform its function well? A rating of 5 would indicate that the furniture used for eating is exceptional in this respect, perhaps because for various reasons it is especially well designed for mealtime activities; a rating of 4 would indicate that it was above average; 3 would be average; 2 would indicate there is a weak spot or two in the design of the furniture for mealtime activities; and 1 would indicate that the furniture designed for eating does not serve its function well at all in the habitat.

For each item, six aspects are rated and space is provided at the end for comments. The first aspect is performance of function: whether it works as it should and does the job for which it was designed. The second is ease of maintenance: whether cleaning, repairing, and servicing are simple and easy to accomplish. The third is convenience of location: whether the item is normally stored or put in a place where it is accessible but not in the way. The fourth is comfort in use: whether it is comfortable while in use. The fifth is aesthetic quality: whether the item is attractive and pleasing. The sixth is safety: whether the item is safe and as free from danger as possible.

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* The scales presented in this report have been reduced for ease of presentation. Scales to be used by evaluators will have adequate space for pertinent comments.

Please use the column for comments liberally, particularly in explaining ratings of 2 or 1. If an item is nonexistent in the habitat, leave the rating spaces blank, but feel free to comment whatever the circumstance.

AREA A: BIOLOGICAL SUPPORT

The Item	Performance of Function	Ease of Maintenance	Convenience of Location	Comfort in Use	Aesthetically Pleasing	Safety	Comments
Food/Drink Plates							
Eating Utensils							
Stove, Burners/Food Preparation Area							
Food Preparation Utensils							
Nonrefrigerated Food Storage Areas							
Refrigerated Food Storage							
Drinking Water Dispenser (if available)							
Furniture Used During Eating							
Medicine Storage Area							
Medicines Available							
Hygiene Paper Towels, Kleenex, Toilet Paper							
Towels							
Sinks for Hygiene							
Shower							
Bath (if available							
Soaps							
Shaving Equipment							

AREA A: BIOLOGICAL SUPPORT (Continued)

The Item	Performance of Function	Ease of Maintenance	Convenience of Location	Comfort in Use	Aesthetically Pleasing	Safety	Comments
Hygiene (Continued) Nail Equipment							
Dental Equipment							
Hair Care Equipment							
Storage Areas for Towels/Hygiene Equipment							
Waste Disposal Litter Containers							
Garbage Containers							
Head or Toilet							
Housekeeping Vacuum (if available)							
Broom/Mop (if available)							
Window Washing Equipment (if available)							
Sink Cleaning Equipment							
Head Cleaning Equipment							
Ironing Equipment (if available)							
Clothes Cleaning Equipment (if available)							
Storage Areas for Housekeeping Equipment							
Exercise Exercise Equipment (if available)							
Areas for Exercise (if available)							

AREA A: BIOLOGICAL SUPPORT (Continued)

The Item	Performance of Function	Ease of Maintenance	Convenience of Location	Comfort In Use	Aesthetically Pleasing	Safety	Comments
Sleep Beds							
Sheets and Blankets							
Pillows							
Sleeping Area							
Storage for Sheets, Blankets, etc.							

AREA B: TASK SUPPORT

The Item	Performance of Function	Ease of Maintenance	Convenience of Location	Comfort in Use	Aesthetically Pleasing	Safety	Comments
Equipment for Repairs Tools							
Tool Storage Area							
Reading and Writing Tasks Reading and Writing Areas							
Desks (if available)							
Reading and Writing Storage							
Chairs							
Lamps							
Pens, Pencils, Paper, Stationary, Erasers, etc.							
Typewriter (if available)							
Tables (if available)							
Thinking and Personal Reflection (if available) Area for Private Reflection							
Specialized Task Support (if available) Working Area							
Instruments and Equipment							
Storage							
Clothes Making and Clothes Repair (if available) Sewing Equipment							
Sewing Storage Area							
Task Support in General Working Area							

AREA C: EDUCATIONAL AND INFORMATIONAL

The Item	Performance of Function	Ease of Maintenance	Convenience of Location	Comfort in Use	Aesthetically Pleasing	Safety	Comments
Cook Books (if available)							
Books on Medical Care (if available)							
Equipment Manuals or Directions							
Specialized Task Books (if available)							
Leisure Time Books							
Book Storage Area							
Access to News							
Clocks							

AREA D: RECREATIONAL/LEISURE TIME SUPPORT

The Item	Performance of Function	Ease of Maintenance	Convenience of Location	Comfort in Use	Aesthetically Pleasing	Safety	Comments
Musical Instruments (if available)							
Recorded Music							
Games							
Leisure Time Space							
Television							

AREA E: SOCIAL AND COMMUNICATION SUPPORT

The Item	Performance of Function	Ease of Maintenance	Convenience of Location	Comfort in Use	Aesthetically Pleasing	Safety	Comments
Social Area (e.g., Living Room) Furniture							
Telephone (if available)							
Social Area Layout							

AREA F: MISCELLANEOUS

The Item	Performance of Function	Ease of Maintenance	Convenience of Location	Comfort in Use	Aesthetically Pleasing	Safety	Comments
Floor Coverings							
Clothing Storage							
Curtains, Shades (if available)							
Access to Power							
Access to Water							
Temperature Regulation							
Art or Aesthetic Additions							
Mirrors							
Grooming Area							
Grooming Equipment							

AREA G: GENERAL

The Item	Performance of Function	Ease of Maintenance	Convenience of Location	Comfort in Use	Aesthetically Pleasing	Safety	Comments
The Entire Habitat							

PART 2

AMOUNT OF SENSIBLE VARIETY IN HABITAT

What degree of sensible variety is there in this habitat? Use the following five scales to indicate this by placing a check over the appropriate place on each scale. Use the average habitat of your experience as a point of comparison; that is, a check over the part of the scale labeled "average" would indicate that the habitat you are rating is about the same as most average habitats in amount of variety. Also, along with placing a check on the scale to indicate your rating of the habitat in question, please place an "X" on each scale for where you would put your ideal habitat. Thus you should put two ratings down for each of the five variety scales: the first, a check, will be for the habitat you are now rating: the second, an "X" will be for what you would consider to be the perfect habitat.

Compared to what would be desirable in a habitat, the habitat being rated has what degree of sensible variety? Use the following 5 scales to indicate this:

1. Amount of variety in visual input that is immediately accessible to the eye when standing in a central location in the habitat:

Very little perceivable variety to the eye	An average variety of colors, shapes, contrasts, shades, and movements perceivable to the eye	An unusual amount of perceivable visual input variety

2. Amount of temporal variety in visual input:

A small amount of perceivable temporal visual change	An average amount of visual variety in changes that occur over the time course of a day	An unusually high amount of perceptible change of visual input over time

3. Amount of immediately perceptible variety in sounds:

Very little variety in perceptible sound at most times	An average amount of variety in perceptible sounds	An unusually high amount of variety in perceptible sound

4. Amount of temporal variety in sound:

Very little variation over time in sound	An average amount of variation over time in sound	An unusually high amount of variation over time in sound

5. Amount of immediately perceptible variation in tactile feelings:

Very little tactile variation	An average amount of perceptible tactile variation	An unusually high amount of tactile variation

(IT is assumed that there will not be a high amount of tactile variation over time.)

PART 3

ENVIRONMENTAL ASSESSMENT

Background

Evaluator:_____________Organization:______________________

Specific Status
and/or Duty:____

Test Type: Pre-mission, Mission, Post-mission
(Circle One)

INSTRUCTIONS

Circle E if your rating is excellent, V for very good, F for fair, and P for poor. Rate whether or not the types of environment support listed in the left column are available in the various activity areas listed along the top. Your comments will be of at least as much help as your ratings. Use the space below the ratings for comments. If additional comments are required please continue on back of rating sheet.

ENVIRONMENT ASSESSMENT

	SLEEP		FOOD	RECREATION		SOCIAL	WORK				HYGIENE		OVERALL
Support From Habitat	Sleep	Eating	Food Preparation	Exercise and Active Recreation	Games, Books Entertainment	Social Inter-Action	In-Habitat Science Experiments	In-Habitat Repair and Maintenance	Access to Extra Habitat Environment	Work in Extra Habitat Environment	Waste Elimination	Washing, Showering, Body Cleansing	In General
Is there enough room?	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P		E V F P	E V F P	E V F P
Is the lighting of the area satisfactory?	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P
Is the site or location of the area used for the activity satisfactory?	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	
Is the physical layout of the area satisfactory?	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P
Is it quiet enough?	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P		E V F P	E V F P	E V F P
Is there a satisfactory lack of odor?	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P		E V F P	E V F P	E V F P
Is the temperature satisfactory?	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P
Is the humidity satisfactory?	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P		E V F P	E V F P	E V F P
Is there enough time allowed?	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	
Are the times of day available for the activity good ones?	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	
Is there good selection and good variety?		E V F P		E V F P	E V F P		E V F P						
How does the habitat affect the activity in general?	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	E V F P	

FOLDOUT FRAME 1

FOLDOUT FRAME 2

APPENDIX E

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APPENDIX F

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